The document and process conversion measures necessary to comply with this revision shall be completed by 17 August 2012.

NOT MEASUREMENT SENSITIVE

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# PERFORMANCE SPECIFICATION

# PRINTED CIRCUIT BOARD/PRINTED WIRING BOARD, GENERAL SPECIFICATION FOR

Comments, suggestions or questions on this document should be addressed to: DLA Land and Maritime, ATTN: VAC, P.O. Box 3990, Columbus, OH 43218–3990 or e–mailed to 5998.Documents@dla.mil. Since contact information can change, you may want to verify the currency of address information using the ASSIST Online database at Universal Resource Locator (URL) https://assist.daps.dla.mil/.

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This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification establishes the general performance requirements for printed circuit boards or printed wiring boards (hereafter designated printed board) and the verification requirements for insuring that these items meet the applicable performance requirements. Certification and qualification to this specification allows manufacturer's to apply the Qualified Manufacturers List (QML) (see 6.4.30) program to printed boards procured to non–QML documents such as MIL–PRF–55110 and MIL–P–50884 (see 6.3.5 and 6.5). The intent of this specification is to allow the printed board manufacturer the flexibility to implement best commercial practices to the maximum extent possible while still providing product that meets military performance needs (see 6.3.4). The principle concepts which allow this flexibility are as follows:

a. The manufacturer forms an internal quality review system or organization referred to in this document as the Technical Review Board (TRB) (see 6.4.48). The TRB is responsible for the implementation of a quality management (QM) plan (see 6.4.39). The implemented QM plan becomes the manufacturer's quality management (QM) program (see 6.4.40).

b. A relationship is established between the manufacturer and the qualifying activity (see 6.4.35).

1.2 Summary of implementation. The process used to implement this specification can be summarized as follows:

a. Self-assessment: The TRB verifies the implemented QM plan.

b. Certification: The qualifying activity leads a team to validate the TRB's effectiveness in implementing their QM plan.

c. Qualification: The manufacturer demonstrates its technology capability (see 6.4.46) to produce printed boards.

d. Maintenance: The TRB keeps the qualifying activity informed on the status of its QM program.

The quality assurance requirements outlined herein are for all printed boards built on a manufacturing line which is controlled through a manufacturer's QM program and has been certified and qualified by the qualifying activity in accordance with requirements herein and the applicable specification sheet (see 3.3.1 and 6.4.44). This specification requires a manufacturer to establish a process flow baseline (see 6.4.25). After listing of a qualified technology on the QML, the manufacturer is to continually meet, or improve, the established baseline of certified and qualified procedures, the QM program, the manufacturer's system of review, the status reporting, and quality and reliability assurance requirements for all QML printed boards. The manufacturer may present alternate methods of addressing the requirements contained in this specification and the applicable specification sheet. These alternate methods shall be approved by the qualifying activity. Additional information on the QML process and the philosophy it is based on is available in 6.3.4 herein.

1.3 Description of this document. The main body of this document describes the requirements for obtaining a QML (see 6.4.30) listing. The appendices of this document are intended to aid the manufacturer in developing its verification program. Appendix A describes a quality management approach using a TRB concept. Appendix B contains qualification procedure requirements. Appendix C contains the conformance inspection requirements. Appendix D describes techniques for test optimization (see 6.4.49). Appendix E provides statistical sampling, basic test, and inspection requirements. Sectional specification sheets (see 6.4.44) contain the performance requirements and verification methods for printed boards by technology. Detailed requirements, specific characteristics, and other provisions which are sensitive to the particular intended use of printed boards are to be specified in the printed board procurement documentation (see 6.4.21). Appendices F and G contain verification methods that are referenced by the applicable specification sheet.

## 2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4 and 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirement documents cited in sections 3, 4 and 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

(See supplement 1 for list of specification sheets.)

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or https://assist.daps.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111–5094.)

2.3 Non-Government publications. The following document forms a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

IPC – ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES (IPC)

IPC–T–50 – Terms and Definitions for Interconnecting and Packaging Electronic Circuits.

(Copies of this document can be obtained through the IPC – Association Connecting Electronics Industries, 3000 Lakeside Drive, Suite 309 S, Bannockburn, IL 60015–1249 or be ordered online at URL http://www.ipc.org.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

## 3. REQUIREMENTS

3.1 Specification sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheet and the applicable printed board procurement documentation. In the event of any conflict between the requirements of this specification and the specification sheet, the latter shall govern.

3.1.1 Printed board detail requirements. The individual item requirements for printed boards delivered under this specification shall be as specified in the applicable MIL–PRF–31032 specification sheet or performance specification, and documented in the printed board procurement documentation.

3.1.2 Reference to specification sheet. For the purposes of this specification, when the term "specified" is used without additional reference to a specific location or document, the intended reference shall be to the applicable MIL–PRF–31032 specification sheet or performance specification.

3.2 QML qualification. Printed boards furnished under this specification shall be products that are manufactured by a manufacturer authorized by the qualifying activity for listing on QML–31032 before contract award (see 4.2 and 6.3).

3.3 General. The manufacturer of QML printed boards, in compliance with this specification, shall have, or have access to, and use production and verification facilities, and a QM program to assure successful compliance with the provisions of this specification and the applicable specification sheet. Adequacy of a printed board manufacturer to meet the requirements of this specification shall be determined by the qualifying activity. Only printed boards that meet all the requirements of this specification, the applicable specification sheet, and of the printed board procurement documentation shall be marked as compliant and delivered. The QML certification brand (3.8.3) indicates compliance to all the performance provisions of this specification, the applicable specification sheet, and the printed board procurement documentation.

3.3.1 Methods of implementation. The requirements described herein, or in the applicable specification sheet, can be addressed by the TRB by using one of three different methods as follows:

a. As specified herein or in the applicable specification sheet.

b. Approval by the qualifying activity of an alternate method that assures the same, or superior, quality and reliability with equivalent effectiveness as defined by the requirement.

c. Demonstration to the qualifying activity and quality system audit team, when applicable, that the requirement is not applicable to the manufacturer’s technology.

These implementation methods are detailed further in table I.

TABLE I. Implementation examples.

| Option | Definition | Typical examples | Implementation procedures |
|---|---|---|---|
| Meet the requirement as written | The manufacturer performs the test or requirement as specified. | Self explanatory | The manufacturer implements the test or requirement into its internal documentation, verified during certification. |
| Alternate method to the requirement | The manufacturer assures that the intent of the requirement is met, but does not perform the test/requirement exactly as written. | a. Replacement of a test with statistical process control (SPC) or alternate method.<br>b. Historical data analysis shows that the requirement is met.<br>c. Design verification/validation shows that the process is capable of meeting the requirement.<br>d. Requirement does not address new materials, technologies, or designs. | The alternate method and appropriate justification are approved by the manufacturer's TRB. |
| Elimination of the requirement | The manufacturer proves that the test or requirement is non-value added | a. Test does not stress the process adequately.<br>b. Historical data analysis shows that the test does not induce failures. | Elimination is achieved in the same manner as alternate methods described above. |
| | The printed board will not comply with the test or requirement due to technology limitations. | Configuration or design of the printed board (i.e., size, mass, material) is incompatible with the test method. | The exception shall be documented in the applicable printed board procurement document. |
| | Application has no need of the requirement. | The printed board will not experience the particular stress in the assembly or usage application. | The exception shall be documented in the applicable printed board procurement document. |

3.3.2 Conflicting requirements. In the event of conflict between the requirements of this specification and other requirements of the applicable specification sheet or the qualifying activity approved QM plan, the precedence in which documents shall govern, in descending order, is as follows:

a. The applicable printed board procurement documentation. Acquisition requirements (see 6.2) may be provided in the order or contract; however, if any of the provisions of this specification, the applicable specification sheet or the QM program are not met, the resulting printed boards cannot be provided as compliant printed boards (i.e., printed boards cannot be "QML" or "Q" branded or certified to the applicable specification sheet).

b. The qualifying activity approved QM plan.

c. The applicable specification sheet.

d. This specification.

e. Specifications, standards, and other documents referenced in section 2.

NOTE: "QML" or "Q" branded printed boards may incorporate test optimization under special criteria defined within this specification (see 4.6 and appendix D) and as defined in the manufacturer's QM plan.

3.3.3 Terms and definitions. For the purposes of this specification, the terms and definitions of IPC–T–50 and those contained in 6.4 herein shall apply and shall be used in the applicable specification sheet and applicable printed board procurement documentation wherever they are pertinent.

3.4 Certification of conformance. Unless otherwise specified by the printed board procurement documentation (see 6.2), a certificate of conformance for compliant printed boards shall be forwarded to the acquiring activity (see 6.4.1). Unless otherwise specified by the printed board procurement documentation, when a certificate of conformance for compliant printed boards is supplied, it shall include the following information, as a minimum:

a. Manufacturer's name and address.

b. Customer's name and address.

c. Manufacturer's CAGE (Commercial and Government Entity) code (see 6.4.6).

d. Printed board description (specification sheet number with revision level and printed board procurement documentation number).

e. Lot date code (see 3.8.4).

f. Quantity of printed boards in shipment from manufacturer.

g. Statement certifying printed board conformance to the applicable specification sheet and printed board procurement documentation and traceability. The printed boards shall be capable of passing the conformance inspections in accordance with the requirements of the applicable specification sheet whether or not the actual testing has been performed.

h. The date of transaction.

i. The name of the company official approving the certificate of conformance. The manufacturer shall have a method for authenticating the approval of certificates of conformance for printed boards compliant to the applicable specification sheet.

3.5 QM program (see A.3). The printed board manufacturer shall have in place a QM program.

3.5.1 Manufacturer's internal review system. The manufacturer shall implement a dedicated internal system of quality review, hereafter known as the TRB. The TRB shall document, review, approve, and be responsible for the implementation of the QM program (as reflected in the QM plan), maintenance of all certified and qualified processes, process change control, reliability data analysis, failure analysis, corrective actions, QML printed board recall procedures, and qualification status of the technology.

3.5.2 QM plan (see A.3.2 and A.4). The manufacturer's QM plan shall reflect the major elements of the QM program. The QM plan shall be kept current and shall reflect all major changes. Whenever the TRB makes major changes (see A.5.1.2) to the QM plan, copies of the updated QM plan shall be submitted to the qualifying activity for review.

3.5.3 Self–assessment program (see A.4.5). The manufacturer's TRB shall ensure that a self–assessment program is implemented and perform evaluations on a periodic basis of all areas controlled by the QM plan. Results of the self–assessment, including corrective actions of deficiencies and concerns, shall be documented by the TRB and shall be made available for review to the qualifying activity.

3.5.4 Change control procedures (see A.3.3 and A.5). The manufacturer shall have a system for change management. This system shall include a process to monitor changes and the assessment of those changes as to the impact to customers.

3.6 Requirements for listing on QML–31032. To be listed on QML–31032, the qualifying activity will verify the manufacturer's compliance to the QML certification requirements (see 3.6.1) and the manufacturer shall demonstrate compliance to the QML qualification requirements (see 3.6.2).

3.6.1 QML certification. The manufacturer shall meet the minimum requirements in this section for QML certification of a QM program and process flow by which printed boards are fabricated and inspected. The certification process will involve a qualifying activity review of the manufacturer's QM plan and self-assessment results prior to an on-site audit of the manufacturer's facility(ies). During the on-site audit, the qualifying activity will determine adequacy and compliance of the manufacturers QM program to the requirements as specified herein and will report its findings and recommendations to the manufacturer's TRB. Qualifying activity approval of the manufacturer's QM program and process flow will result in certification and is a mandatory precondition to a QML listing.

3.6.1.1 QM program implementation. The manufacturer shall implement the QM program in accordance with the requirements of the TRB approved QM plan. The manufacturer shall make available to the qualifying activity all data or documents needed to support its QM program and procedures (see A.3.4).

3.6.1.2 Manufacturer self–assessment system. The manufacturer shall establish a self–assessment system to verify the compliance of its QM program to the TRB approved QM plan (see A.4.5). Unless otherwise approved by the qualifying activity, the manufacturer self-assessment shall be performed at least annually.

3.6.1.3 Qualifying activity on-site audit. The manufacturer shall demonstrate to the quality system audit team (see 6.4.37) that the QM program is being implemented in accordance with the approved QM plan during the quality system audit (see 6.4.36) and with each re-audit of the quality system. Qualifying activity representatives shall lead quality system audit teams. Quality system audit team access to manufacturing and testing facilities and operators shall be required during the on-site audit. During the on-site audit, the quality system audit team shall verify the adequacy of the manufacturer's QM program to achieve at least the same level of quality as could be achieved by complying with appendix A and the applicable specification sheet. The quality system audit team shall also verify the adequacy of the manufacturer's process flow, assessing the process flow's capability to produce printed boards that can meet the performance verifications defined in applicable specification sheet. The quality system audit team may also evaluate the manufacturer's capability for holding critical processes within established limits at specified points and continuously maintaining this capability during production. Each portion of a QML manufacturer's process flow, including contract service operations, may be demonstrated independently, but the quality system audit by the quality system audit team will assess a complete technology flow. The qualifying activity reserves the right to perform on-site quality system audits of any facilities, or technologies, that the manufacturer plans to add to its QML–31032 listing. Quality system audit of contract service operations and third party suppliers are the responsibility of the manufacturer, but the qualifying activity reserves the right to perform on-site audit at any contract service operations that are a portion of a manufacturer's process flow. Deficiencies and concerns found during the quality system audit shall be noted by the quality system audit team and provided to the TRB during the exit critique.

3.6.1.4 Letter of certification. After the on-site quality system audit, and upon qualifying activity approval of correction of all deficiencies and concerns, the qualifying activity will issue a letter of QML–31032 certification to the manufacturer.

3.6.1.5 Re–audits. Following initial certification, a quality system audit team will periodically inspect the printed board manufacturer's facilities and equipment, review its processes and techniques, and validate the implementation of the QM program and records. The interval between on-site quality system audits shall be at the discretion of the qualifying activity. The qualifying activity will determine the interval based on the manufacturer's TRB self–assessment reports or retention reports (as applicable), customer feedback, and other indications of the manufacturer's maintenance of its QML system.

3.6.2 QML qualification requirements. Printed boards furnished under this specification shall be products which are authorized by the qualifying activity for listing on QML–31032. Qualification testing shall be performed in accordance with the approved qualification test plan. (See 4.2 and appendix B for the requirements for qualification.)

3.6.2.1 QML listing. A notification of qualification will be issued upon successful completion of the qualification process and the approval of the qualification documentation by the qualifying activity. Issuance of the notification of qualification will coincide with listing of the manufacturing facility on QML–31032 for the applicable technology.

3.6.2.2 Addition of capabilities, materials, and processes (see B.3.3.3). After the initial qualification is accomplished, and with the approval of the qualifying activity, an established QML–31032 listed manufacturer may add other fabrication capabilities, materials, processes, and test facilities upon completion of the TRB self–assessment and approval, appropriate qualification testing, and qualifying activity off-site review or on-site audit and approval.

3.7 Conformance inspection. All printed boards delivered in accordance with this specification shall be capable of meeting all performance requirements of the applicable specification sheet and printed board procurement documentation when verified in accordance with 4.3 herein.

3.7.1 Conformance inspection assessment. In the event the TRB determines that the conformance inspection requirements are not met, the TRB shall make an assessment of the printed boards and the qualifying activity shall be notified of the decision.

3.8 Marking. Marking of compliant printed boards and their associated test coupons shall be in accordance with the following requirements and the identification and marking provisions of the printed board procurement documentation. The marking shall be permanent, legible, complete, and shall meet the marking adhesion requirements of the applicable specification sheet. If any additional marking is used or required by the printed board procurement documentation, it shall in no way interfere with the marking required herein, and shall be visibly separated. Only the approved for listing on QML–31032 manufacturer is authorized to apply the QML brand (see 3.8.3).

3.8.1 Full marking. Unless otherwise specified by the printed board procurement documentation, the following full marking shall be placed on each printed board and test coupon strip:

a. "QML" or "Q" brand (see 3.8.3).

b. Printed board Part or Identifying Number (PIN) with revision level (when applicable) or other special coding system detailed by the procurement documentation.

c. Lot date code (see 3.8.4).

d. QML manufacturer's CAGE code (see 3.8.5).

e. Traceability (see 3.9).

3.8.2 Minimum marking. When the physical size of the printed board precludes the placement of the information specified in 3.8.1, the minimum marking shall be as specified in the printed board procurement documentation. In those cases where full marking requirements are not on the printed board, the full marking shall be placed on the unit package.

3.8.3 QML brand. All printed boards acquired to, and meeting the requirements of this specification, the applicable specification sheet, the printed board procurement documentation, and that are produced by manufacturers approved for listing on QML–31032 shall bear the "QML" brand. The QML brand abbreviation "Q" may be used for small printed boards. The application of the QML brand shall constitute certification by the manufacturer that all requirements of the applicable specification sheet, the printed board procurement documentation and this specification have been satisfactorily met. In the event that a lot fails to pass inspection and is not dispositioned as scrap, the manufacturer shall remove or negate the QML brand, and all reference to this document from the sample(s) and also from all printed boards represented by the sample.

3.8.3.1 Reduction of specified requirements. The "QML" brand or its abbreviation shall not be used on any printed board acquired under contracts or orders which permit or require any changes that eliminates test or inspections not specified by the approved QM program and approved by the TRB. If any exceptions are taken to this specification or the applicable specification sheet (other than approved TRB modifications, see 3.3 and appendix D), the "QML" or "Q" brand shall not be used.

3.8.4 Lot date code. Unless otherwise specified by the acquiring activity, printed boards shall be marked by a unique code to identify the period during which printed boards in that production lot were manufactured. The marking method used and time of application of the lot date code shall be defined by the QM program. The first two numbers in the code shall be the last two digits of the number of the year, and third and fourth numbers shall be two digits indicating the calendar week of the year. When the number of the week is a single digit, it shall be preceded by a zero. Reading from left to right or from top to bottom, the code number shall designate the year and week, in that order (e.g., 1251 equals week 51 of 2012).

3.8.5 Manufacturers' CAGE code. The QML manufacturer's designating CAGE code number shall be used only by the manufacturer to whom it has been assigned and only on those printed boards manufactured at the manufacturer's basic plant (see 6.4.2).

3.8.6 Serialization. Unless otherwise specified by the printed board procurement documentation, each printed board and its associated test coupon shall be marked with a serial number traceable to the production panel.

3.9 Traceability. Traceability shall be retained by the manufacturer for a minimum of three years after delivery of the compliant printed boards, and shall be readily available for review upon request of the acquiring activity or qualifying activity.

3.9.1 Printed board materials. Traceability shall be such that for each production lot of printed boards, all printed board materials specified or used shall be traceable to a material production lot, inspection lot, or other specified grouping.

3.9.2 Process traceability. Each printed board, or each group of printed boards that has been fabricated as a production lot, shall be identifiable such that the complete manufacturing history shall be traceable. The history should include, as a minimum, the performance date of all identified production process steps, the procedure specification, any rework steps, and the identification of the equipment used, and operator performing the process steps.

3.9.3 Production lot. The manufacturer shall maintain production lot traceability for all printed boards. Each test coupon shall be identifiable with those corresponding printed boards produced on the same panel. All separated individual test coupons shall have their traceability maintained back to the production panel or qualification test vehicle from which the test coupons were separated.

3.9.4 Inspection lot. Inspection lot identification shall be maintained from the time the inspection lot is formed until the lot is dispositioned. Inspection lot traceability shall be maintained to the production lots from which it was formed and shall reflect the final inspection disposition of all printed boards in the inspection lot.

3.10 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.11 Workmanship. Printed boards shall be processed in such a manner as to be uniform in quality and shall be free from other defects that will affect life, serviceability, or appearance.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Qualification inspection (see 4.2).

b. Conformance inspection (see 4.3).

c. Maintenance and retention of qualification (see 4.4).

4.1.1 General. All printed boards offered and shipped in compliance with this specification and the applicable specification sheet shall meet the performance requirements specified. The manufacturer is responsible for verifying that printed boards delivered meet the performance requirements as stated in the applicable specification sheet. The manufacturer is responsible for developing a verification program which shall meet this requirement. The manufacturer may address the requirements of this specification as written, develop an alternate or new methodology, or eliminate a specification sheet requirement that is not applicable to their technology through its approved test optimization program (see 4.6). Prior to the manufacturer being certified, the actual verification program to be used shall be reviewed and approved by the qualifying activity. After certification, any test optimization shall also be reviewed and approved by the qualifying activity, or the manufacturer's TRB, prior to implementation. The absence of any inspection requirements in the applicable specification sheet shall not relieve the manufacturer of the responsibility of ensuring that all printed boards submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements; however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Verifications for QML–31032 listing. Manufacturers of printed boards furnished as compliant to this specification shall obtain a QML–31032 listing from the qualifying activity. Qualifying activity approval of the manufacturer’s QM program, process flows, and qualification of the technology will result in the manufacturers receiving a QML certification. Technology capabilities for manufacturing processes and materials which have completed qualification inspection will be listed on the QML following approval by the qualifying activity. The qualifying activity shall provide procedures to obtain a QML certification and QML listing. This verification process will require a qualifying activity on-site audit of the manufacturer's facility.

4.2 Qualification inspection. In order to receive a QML–31032 listing, manufacturers shall demonstrate the capability of their processes and materials to produce printed boards that meet the performance requirements of the applicable specification sheet. Manufacturers of advanced or emerging technologies shall also perform, as part of their qualification inspection process, technology characterization in order to define the technology. Qualification inspection shall be performed at a laboratory acceptable to the qualifying activity (see E.6.1) on qualification test vehicles produced with material, equipment, and procedures that will be used in subsequent production. Qualification inspection shall be performed in accordance with the requirements of appendix B.

4.3 Conformance inspection. Conformance inspection shall demonstrate the printed boards conform to the performance requirements of the applicable specification sheet and the design requirements of the printed board procurement documentation. The requirements concerning conformance inspection shall be as specified in appendix C.

4.4 Maintenance and retention of qualification. In order to maintain qualification status after initial qualification, the manufacturer shall perform periodic conformance inspection (see A.4.12) and capability verification inspection (see A.4.16), or a TRB approved alternate assessment procedure as defined in the QM plan. Retention of QML–31032 status shall also be compliant with the traceability requirements of 3.9.

4.5 Process control. The manufacturer shall establish and maintain process production controls, quality controls, and inspections at appropriately located points in the manufacturing process in accordance with the approved QM plan to assure continuous control of quality of materials, individual layers, and assembled layers including contract service operations and testing. These controls and inspections shall be adequate to assure compliance with the printed board procurement documentation and quality requirements of printed boards manufactured to this specification and the applicable specification sheet.

4.5.1 Process monitoring. A process monitoring system shall be used by the manufacturer to control key processing steps to insure product yield and process reliability. The monitoring system can use various test vehicles, methods, and measurement techniques. The critical operations to be monitored shall be determined by the manufacturer based on its experience and knowledge of its processes. The resulting data shall be analyzed by appropriate process control methods to determine control effectiveness.

4.5.2 Process optimization. Following the initial process characterization, the manufacturer shall optimize the process parameters. Process characterization should be conducted on the entire process (i.e., conversion through delivery). Process optimization is accomplished through identification of optimal targets and continual reduction of variation around those targets. A matrix shall be developed that identifies failure mechanisms and their controls. The ability to maintain control of critical process points will determine process capability.

4.6 Test optimization. Unless otherwise specified by the printed board procurement documentation, any specified verification test or inspection may be reduced, modified, moved, or eliminated by the TRB provided the final printed board requirements are met. In this manner, a manufacturer may use an alternative method to the method specified in this specification or the applicable specification sheet to evaluate the fabricated printed boards if the alternate method verifies the same performance requirement. The manufacturer may decrease the occurrence or sample size of the test, or inspection, if it is shown that the test or inspection can be performed less frequently. Furthermore, the manufacturer may eliminate a test or inspection if it is shown that the test or inspection is not necessary. It is the manufacturer's responsibility to show how their verification program, and any changes to it, meets the requirements of this specification and the applicable specification sheet. The manufacturer shall analyze the impact of major changes and their effect on previously approved test optimization. Regardless of any verification modifications, the manufacturer shall supply printed boards capable of passing any test or inspection prescribed in the applicable specification sheet. Appendix D provides guidelines for test optimization.

## 5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the Military Services system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD–ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. Printed boards conforming to this specification are intended primarily for use in electronic and electrical equipment applications.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.

b. Number of the applicable specification sheet (see 3.1).

c. Title, number, and date of the printed board procurement documentation.

6.3 Certification and qualification.

6.3.1 Application for certification. Application for certification should be requested from the qualifying activity. For assistance and additional information concerning the certification process, please contact DLA Land and Maritime, ATTN: VQE, P.O. Box 3990, Columbus, OH 43218–3990; or by facsimile (614) 693–1659; or by electronic mail at "5998.Qualifications@dla.mil".

6.3.2 Certification. Qualifying activity approval of the manufacturer's QM plan and program will result in QML certification and is a mandatory precondition to a QML–31032 listing. During the on-site quality system audit, the qualifying activity will verify the adequacy of the manufacturer's QM program to achieve at least the same level of oversight as could be achieved by complying with appendix A.

6.3.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in Qualified Manufacturer's List (QML No. 31032) whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from DLA Land and Maritime, ATTN: VQE, P.O. Box 3990, Columbus, Ohio 43218–3990 or by email "5998.Qualifications@dla.mil" or at URL http://www.landandmaritime.dla.mil/programs/qmlqpl. An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at URL https://assist.daps.dla.mil/. In order to be listed in the QPD for QML–31032, manufacturers will also maintain an active registration in the Central Contractor Registration (CCR) database (see 6.4.4). Qualified capabilities details may be found in the Qualified Products Database Supplemental Information Sheet (QPDSIS) for QML–31032 available at URL http://www.landandmaritime.dla.mil/programs/qmlqpl/.

6.3.4 Discussion. The foundation of QML is the instillment of QM within the manufacturing environment. QM requires that all levels of management and non-management be actively involved in the commitment to quality. Also, a TRB or TRB type system must be established to control, stabilize, monitor, and improve the qualified technology. The TRB should have a QM plan that outlines how the manufacturing operation for a given technology is controlled, monitored, and improved. Key aspects of this plan are the establishment of process control, customer return programs, corrective action procedures, quality improvement, and any other approaches used to control and improve printed board quality.

This document describes procedures and requirements for a manufacturer to obtain a listing on QML–31032 for printed boards. The QML program enables the manufacturer to produce printed boards without the need for extensive end-of-manufacturing qualification testing and quality conformance inspection on each printed board design. End-of-manufacturing verification testing can be replaced with in-line monitoring and testing and process controls. Also, test vehicles in lieu of actual printed boards, such as the conformance inspection vehicle can be used to assess the technology.

The quality management philosophy, leading to QML, is a process by which a manufacturer acquires a process flow certification and qualification. On-going monitoring techniques will be used to maintain QML status. The process flow consists of facilities and procedures appropriate to accomplish the conversion of customer requirements, fabrication, and testing of printed boards.

The applicable specification sheet identifies the generic performance requirements and the baseline tests and inspections used to verify each lot of printed boards. These tests and inspections can be reduced or changed by the manufacturer's TRB when data on the technology indicates that such changes are appropriate. The philosophy of QML incorporates the idea that high quality printed boards can be obtained without excessive testing or inspecting if the processes are properly monitored and controlled at each step of the process flow.

6.3.5 Application of the QML program to other specifications or documents. QML–31032 certified manufacturers may supply QML compliant printed boards to documents or drawings specifying QPL compliance, provided that they are qualified to the same technology (see 6.4.45) under a MIL–PRF–31032 specification sheet and meet or exceed the design complexity for that specified QPL technology. The manufacturer should not claim or certify compliance to the QPL document unless the printed boards are completely compliant to the QPL document requirements.

6.4 Definitions.

6.4.1 Acquiring activity. The organizational element of the Government that contracts for articles, supplies, or services which may authorize a contractor or subcontractor to be its agent.

6.4.2 Basic plant. The basic plant is the QML listed facility(ies) that assumes full responsibility for all aspects of production and quality. In the event that any portion of production or test is performed at or by a facility other than the basic plant, the basic plant will take whatever actions are necessary to assure the outside activity continually meets the QM plan requirements.

6.4.3 Capability verification inspection. The TRB scheduled periodic process of demonstrating the ability to manufacture printed boards to their current qualification capabilities.

6.4.4 Central Contractor Registration (CCR). The CCR is the primary registrant database for the U.S. Federal Government. CCR collects, validates, stores, and disseminates data in support of agency acquisition missions. Qualified manufacturers should registered in the CCR prior to the award of a contract; basic agreement, basic ordering agreement, or blanket purchase agreement. CCR information can be obtained at URL https://www.bpn.gov/ccr.

6.4.5 Certification. The process by which the qualifying activity determines that the manufacturer is eligible to qualify.

6.4.6 Commercial and Government Entity (CAGE) code. The Commercial and Government Entity Code, or CAGE Code, is a five digit identifier assigned to suppliers to the Federal Government of the United States of America in order to provide a standardized method of identifying a given facility or a specific location. CAGE was previously known as Federal Supply Code for Manufacturers (FSCM) and also the National Supply Code for Manufacturers (NSCM). U.S. based companies can obtain CAGE code information at URL: http://www.dlis.dla.mil/cage_welcome.asp. Non-U.S. based companies can obtain CAGE code information at URL: http://www.dlis.dla.mil/nato_poc.asp.

6.4.7 Compliant printed board. Compliant printed boards meet all the requirements (including qualification) specified in the applicable specification sheet and printed board procurement documentation.

6.4.8 Conformance inspection vehicle. The test vehicle that is used to perform periodic conformance inspection. The conformance inspection vehicles do not have to be a part of a printed board or reside at a specific panel location, however, they can be incorporated into panels, within printed boards, exist separately, or any combination thereof.

6.4.9 Contract services. Any fabrication or testing performed outside the basic plant.

6.4.9.1 Fabrication. Contract services may be used to perform fabricating steps in accordance with processing procedures contained in the QM plan.

6.4.9.2 Test laboratory. Test or inspection facilities outside the basic plant may be used to perform lot conformance, periodic conformance, capability verification, and qualification testing.

6.4.10 Conversion of customer requirements (into manufacturer's internal instructions). A system where the manufacturer compares the customer's requirements to its in-house capabilities (with a feedback system to the design activity) and then initiates actions to deliver printed boards which meet the customer's needs.

6.4.11 Custom technology. An advanced or emerging technology that is not addressed or covered by a MIL–PRF–31032 specification sheet. In order for a manufacturer to certify and qualify custom technologies, the TRB will define and develop the acceptability requirements, sampling plans, technology capability, and the verifications necessary for certification and qualification.

NOTE: A custom technology may include a technology that has heritage for the industry, or it may be a technology that is totally new to the industry.

6.4.12 Data. Factual information (measurements or statistics) recorded as evidence of capabilities and conformance to the prescribed limits. Physical data also may include physical evidence, such as tested (used) and unused test coupons or microsection mounts.

6.4.13 Facility. An organizational structure and collection of designated documentation, services, fabrication, and test equipment used to support the manufacturing, testing, and shipping of printed boards in accordance with a specific process flow.

6.4.14 Failure analysis. The process of examining printed boards to determine the cause of variations of characteristics found to be outside the required limits with the end result that failure modes, failure mechanisms, and failure activating causes will be identified.

6.4.14.1 Failure activating cause. The stresses or forces (chemical, electrical, environmental, or physical) which induce or activate a failure mechanism.

6.4.14.2 Failure mechanism. The process of degradation or chain of events which results in a particular failure mode.

6.4.15 Inspection lot. An inspection lot consists of a single or multiple production lots, accumulated over not more than 30 calendar days, offered for inspection at one time.

6.4.16 Lot conformance inspection. The inspections or tests that are performed for final lot acceptance on each inspection lot of printed boards. The detailed requirements for the lot conformance inspection tests are specified in each MIL–PRF–31032 specification sheet.

6.4.17 Noncompliant printed board. Printed boards produced to acquisition documents that take exception to any of the requirements, inspections, and tests specified herein and in the applicable specification sheet that are not specifically detailed and approved in the QM plan. Noncompliant printed boards cannot make reference to this document or to compliant printed board certification brands.

6.4.18 Percent defective allowable. Percent defective allowable is the maximum observed percent defective which will permit the lot to be accepted after the specified 100–percent inspection.

6.4.19 Periodic conformance inspection. The TRB scheduled periodic process control, process monitor, visual inspection, or applicable specification sheet tests used to demonstrate and evaluate the process and technology in accordance with the manufacturer's approved QM plan. The test vehicle to be used, the parameters to be measured, the frequency of measurement, the number of sample measurements, the conditions of measurement, and the analysis of measurement data will vary as a function of the requirements, capability, and criticality of the operation being measured.

6.4.20 Printed board part number. The term printed board part number refers to a printed circuit or wiring board of a single specific part number and classification for a printed board configuration. All samples of a printed board part number are to be electrically and functionally interchangeable with each other, have the same electrical and environmental test limits, and use the same basic raw materials, and fabrication processes.

6.4.21 Printed board procurement documentation. Printed board procurement documentation consists of the order or contract, the master drawing or detail specification or documentation, production drawings, artwork, or electronic database, as applicable. In the event of conflict between the order or contract and the printed board master drawing, the order or contract takes precedence. If the written order and contract do not agree, the order takes precedence.

6.4.22 Procedure. The specified way to perform an activity. A written or documented procedure usually contains the purposes and scope of an activity; what shall be done and by whom; when, where and how it shall be done; what materials, equipment and documents shall be used; and how it shall be controlled and recorded.

6.4.23 Process. Individual operations involved in the production of printed boards (i.e., conversion of customer requirements, manufacturing, rework, testing, and shipping).

6.4.24 Process control. Process control is the overall system in place to assure consistent process results. Examples of process control include documented procedures, operator training, equipment maintenance and calibration, verification of specified operating parameters (i.e., temperature, pressure, etc.), statistical techniques, and process monitors.

6.4.25 Process flow. The manufacturer's process flow is the specific group of manufacturing processes, inspection and test processes, and material entry points into the flow that defines the manufacturer's specific QML technology. This flow begins with conversion of customer requirements and incoming material, goes through all manufacturing processes including in-process monitors, completed printed board electrical screening, final acceptance verification, and ends at the shipping of the printed boards. The entire process flow is certified during QML certification.

6.4.26 Process flow documentation index. A list of the process, specification, or procedure numbers and titles, document numbers, and revisions which defines the QM program.

6.4.27 Process monitor. Process monitors are the physical verification of a operational parameter of a process output (i.e., plating thickness, ionic contamination, solder coat coverage, etc.).

6.4.28 Process optimization. Process optimization is the mechanism to provide for continuous improvement as equipment and materials technology changes.

6.4.29 Production lot. A production lot consists of panels of printed boards formed into lots at the start of printed board or, when applicable, panel fabrication for homogeneous processing as a group; i.e., same basic raw materials on the same production line, processed under the same manufacturing techniques and controls using the same type of equipment. Processing panels as a homogeneous group is accomplished by any of the following procedures, providing process schedules and controls are sufficiently maintained to assure identical processing in accordance with process instructions of all panels in the lot:

a. Batch processing of all panels in the lot through the same equipment, machine, or process steps simultaneously.

b. Continuous or sequential processing (panel by panel or batch portions of panels) through the same equipment, machine, or process steps.

c. Parallel processing of portions of a production lot through multiple machines or process stations on the same process flow, provided process control assures and demonstrates correlation between stations and separately processed portions of the production lot.

6.4.30 QML. A list of manufacturers, by name and plant address, who have met the certification and qualification requirements stated herein. The listing includes identification of materials and processing capabilities that a printed board manufacturer have qualified.

6.4.31 Qualification. The process by which a manufacturer demonstrates capability to produce a given technology.

6.4.31.1 Add–on qualification. The use of the qualification process to expand the QML listing for previously qualified technologies.

6.4.31.2 Initial qualification. The first time use of the qualification process to obtain a QML listing for a technology.

6.4.32 Qualification test vehicle. Qualification test vehicles are manufacturer defined specimens used to simulate the production processes, materials, and construction techniques used in the manufacture of actual printed boards. Qualification test vehicles are defined based on the manufacturer's assessment of the most critical fabrication and material technologies. Qualification test vehicles can be actual production printed boards, test coupons specifically designed for this purpose, or other media used to establish the printed board manufacturer's capabilities. Qualification test vehicles are to be manufactured in an actual production environment by trained personnel using certified production methods and procedures with proper traceability records.

6.4.33 Qualified Products Database (QPD). A QPD is an electronic version of a Qualified Products List (QPL) and Qualified Manufacturer's List (QML) documents. The QPD has replaced all of the information currently contained on QML–31032. As the data in a specific QPL or QML is converted to database format, the QPL or QML will be phased out and replaced by an equivalent Qualification Dataset (QDS) associated with the specification requiring qualification. For MIL–PRF–31032, a Qualified Products Database Supplemental Information Sheet containing the information once listed on QML–31032 is available from the qualifying activity.

6.4.34 Qualified Products Database Supplemental Information Sheet (QPDSIS). The qualified capabilities for manufacturers may be found in the QPDSIS for any particular MIL–PRF–31032 specification sheet available at URL http://www.landandmaritime.dla.mil/programs/qmlqpl/.

6.4.35 Qualifying activity. The preparing activity or its delegated agent that grants certification and qualification status to QML–31032.

6.4.36 Quality system audit. A step in the certification process by which a quality system audit team determines on the basis of a on-site audit that a manufacturer's process flows are in compliance with the applicable requirements.

6.4.37 Quality system audit team. Selected representatives from the Government (military services, preparing activity, qualifying activity, or other Government agencies) and industry (OEM's, customers, etc.,) involved with certification activities. Qualifying activity representatives will lead quality system audit teams.

6.4.38 Quality assurance. Quality assurance is a planned and systematic pattern of all actions necessary to provide confidence that products and services conform to the established technical requirements.

6.4.39 QM plan. Document(s) which describe the manufacturer's quality policies and the means to accomplish those policies. The QM plan provides an overview of each aspect of the quality system and references the applicable internal procedures.

6.4.40 QM program. The TRB administered program for the interpretation of the requirements of this document and the applicable specification sheet.

6.4.41 Rework. The act of repeating one or more manufacturing operations, or performing alternative techniques, in order to bring a product into compliance with applicable drawings and specifications.

6.4.42 Repair. The act of restoring the functional characteristics of a defective product without restoring the compliance with applicable drawing or specifications.

6.4.43 Self–assessment. The performance of a periodic survey by the printed board manufacturer's designated personnel to evaluate compliance to the QM plan.

6.4.44 Specification sheet. The applicable specification sheet specifies the characteristics to be tested (i.e., the visual, dimensional, chemical, mechanical, electrical, and environmental performance requirements), the test methods and conditions (for verification) to be used, and the requirements to be fulfilled for testing capability. The applicable specification sheet can be a MIL–PRF–31032 specification sheet, an existing Department of Defense printed board specification, an older revision of a Department of Defense printed board specification, or a non-Government standard.

6.4.45 Technology. The materials, processes, and design used to manufacture a specific type of printed boards.

6.4.46 Technology capability. The ability of the manufacturer's technology to produce printed boards that meet the specified performance requirements. The capability of a technology can be determined through testing of critical characteristics of the technology that are known to impact performance and reliability. The data used to determine technology capability may also be produced through other means for mature technologies (e.g., production test data taken over time, design or product qualification test data accumulated for a specific program or customer).

6.4.47 Technology characterization. The process of determining the reliability and performance limits of a technology. Characterization can be determined through tests known to reveal failure modes or mechanisms, testing performed to more severe test conditions than those used for screening, and final acceptance testing of the printed board, or test-to-failure testing.

6.4.48 TRB. The organization(s) identified to develop and implement the QM plan.

6.4.49 Test optimization. The process used by the manufacturer to modify, reduce, or eliminate testing using the best commercial practices available while still assuring all specified performance, quality, and reliability requirements are met.

6.4.50 First piece produced design inspection (first article). The analysis of the first item manufactured in a production run to verify correct setup and process alignment.

6.5 Specification sheet. The specific performance and baseline verification requirements for a printed board technology are specified in the MIL–PRF–31032 specification sheet for a particular technology and will be upgraded periodically to reflect the current state-of-the-art printed boards. Since this document covers the general requirements for certification and qualification of manufacturers, the items listed below should be covered in the applicable specification sheet or TRB generated custom technology that is used in conjunction with this document:

a. Printed board classification technology designation.

b. Performance requirements.

c. Classification of inspection.

(1) Tests and inspections to be performed under qualification inspection.

(2) Tests and inspections to be performed under lot conformance inspection.

(3) Tests and inspections to be performed under periodic conformance inspection.

d. Sequence of test, test method, test condition, limit, cycles, temperature, etc., when not specified, or if not specified in the applicable test method.

e. Provisions for percent defective allowable, where applicable.

6.5.1 Substitutability. Printed boards that are processed and verified using an approved QM program, with procuring activity approval, are substitutable for QPL printed wiring boards of a similar technology, provided all design related parameters specified by the printed board procurement documentation (such as the physical dimensions, metal foil type, surface finish, base material type, and thickness, etc.) are the same. The substitutable printed wiring boards are marked with the "QML" or "Q" certification brand, unless otherwise specified in the order or contract.

6.5.2 Quality and reliability. Printed boards compliant to MIL–PRF–31032 specification sheets are required to meet or exceed the quality and reliability of Department of Defense specifications, such as MIL–P–55110, MIL–PRF–55110, MIL–P–50884, MIL–P–22629, MIL–P–55424, MIL–P–55640, or MIL–P–82585. Printed boards compliant to MIL–PRF–31032 specification sheets are processed through the conversion of customer requirements (see 6.4.10 and A.4.4.1) system of this document to meet or exceed every individual performance requirement or acceptance criteria specified by the customer.

6.6 Printed board procurement documentation. The detailed master drawing portion of the printed board procurement documentation that describes the particular design, construction, and materials should comply with the applicable documentation class of the applicable design standard or documentation with any printed board procured under this specification.

6.7 Environmentally preferable material. Environmentally preferable materials should be used to the maximum extent possible to meet the requirements of this specification. As of the dating of this document, the U.S. Environmental Protection Agency (EPA) is focusing efforts on reducing 31 priority chemicals. The list of chemicals and additional information is available on their website http://www.epa.gov/osw/hazard/wastemin/priority.htm. Included in the list of 31 priority chemicals are cadmium, lead, and mercury. Use of these materials should be minimized or eliminated unless needed to meet the requirements specified herein (see section 3).

6.8 Subject term (keyword) listing.

Capability verification inspection (CVI)
Certification
Conformance inspection vehicle
Lot conformance inspection (LCI)
Panel acceptance plan
Periodic conformance inspection (PCI)
Qualified Manufacturer Listing (QML)
Quality management (QM)
Technology Review Board (TRB)
Test optimization

6.9 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

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APPENDIX A

THE QUALITY MANAGEMENT (QM) PROGRAM

A.1 SCOPE

A.1.1 Scope. This appendix outlines a QM program and has been prepared to allow manufacturers to produce high quality, reliable military printed boards under one quality system utilizing best commercial practices. This appendix is intended to be used by manufacturers in developing a QM program and cross-referencing its QM plan to this appendix. The QM program must demonstrate the methods used to assure conformance to the applicable requirements of this document, including the performance requirements and verification methods of the applicable specification sheet or custom technology. Changes to the QM program can be made by the manufacturer's TRB after achieving QML status with documented reliability and quality data. The approach outlined in this appendix is a proven baseline which contains details of the QM program including the TRB, the QM plan, self–assessment, and change control procedures. This appendix is a mandatory part of this specification. The information contained herein is intended for compliance. However, the manufacturer may offer alternative methods that achieve at least the same level of quality as could be achieved by this appendix.

A.2 APPLICABLE DOCUMENTS. This section is not applicable to this appendix.

A.3 QUALITY MANAGEMENT (QM) PROGRAM

A.3.1 General. The printed board manufacturer shall develop, implement, and maintain a QM program in order to become eligible to be a qualified manufacturer of printed boards. The QM program shall be tailored to the peculiarities of the manufacturer's over-all method of operation, but as a minimum, comply with the applicable requirements specified in A.3.2. The QM program shall be documented in the QM plan.

A.3.2 QM plan. The QM plan shall include the manufacturer's interpretation of how each requirement of this specification and the applicable specification sheet(s) will be implemented. The QM plan may contain an index of references to other documents and procedures which includes the information required. The QM plan that lists the manufacturer's documents and procedures shall be cross-referenced to the QM plan outline listed herein.

A.3.2.1 QM plan outline. The following shall be addressed in the QM plan:

a. TRB system, including structure, duties and methods (see A.4.1).

b. Process flow (see A.4.2) including the process flow documentation index (see 6.4.26).

c. Functional organization chart (see A.4.3).

d. Conversion of customer requirements (see A.4.4.1).

e Self–assessment (see A.4.5).

f. QML status summary and TRB reporting (see A.4.6).

g. Documentation and data retention, storage, and disposition (see 3.9).

h. Continuous improvement (see A.4.7).

i. Failure analysis (see A.4.8).

j. Process control (see A.4.9).

k. Corrective action (see A.4.10).

l. Qualification and add–on qualification testing (see A.4.11).

m. Periodic conformance inspection (see A.4.12 and C.4).

n. Training (see A.4.13).

o. Contract services (see A.4.14).

p. Test optimization (see A.4.15).

q. Capability verification inspection (see A.4.16 and C.5).

r. Document and data control (see A.4.17).

s. Change control (see A.3.3 and A.5).

t. List of verification test and inspection methods.

(1) Test methods which will be performed at the basic plant.

(2) Test methods which will be performed at an outside test facility.

u. Calibration (see E.5.1).

A.3.2.2 Change to the QM plan. After the TRB has approved the QM plan, it shall be kept current and reflect all major changes (see A.5). This includes updating the process flow. The TRB shall not implement any change in certified material, process, or process flow without concurrent change to the process control or quality assurance documents listed in the approved process flow documentation index.

A.3.3 QM program quality system audit process. The effectiveness of the manufacturer's QM program can only be determined over time. The manufacturer shall have a working TRB in place and a comprehensive self-assessment shall be performed by the manufacturer after a sufficient implementation period to get a realistic snapshot of the QM program and TRB effectiveness prior to requesting the qualifying activity to perform a QM program quality system audit. All correspondence sent to the qualifying activity shall be first reviewed by the TRB. These reviews will be used in part to gauge the effectiveness of the TRB. A QM program quality system audit will not be scheduled until the manufacturer has submitted all pre-audit information and has demonstrated a working and effective TRB. The following items are examples of pre-audit submission:

a. Quality planning information.

b. Manufacturer's QM plan (see A.3.2).

c. TRB procedure (see A.4.1) and meeting minutes.

d. Self-assessment results, including those from the process flow and verification demonstration (see A.4.5).

e. Appropriate documents to demonstrate compliance to MIL–PRF–31032 and the applicable specification sheet requirements.

f. List of test methods for lab suitability (see E.6.1).

APPENDIX A

The qualifying activity will review the TRB's pre-audit submissions for compliance to this specification and the applicable specification sheets. Any initial concerns of the qualifying activity will be addressed at this time. Additional information, such as detailed procedures may be requested. The quality system audit will be scheduled once all the pre-audit information is approved. The quality system audit will focus on the TRB, QM plan, and the process flows for each technology for which certification is sought. Once corrective actions have been taken and approved by the qualifying activity, certification will be issued. Upon receipt of certification, manufacturer shall proceed with qualification of the certified technology.

A.4 QM PLAN DETAILS

A.4.1 TRB. The manufacturer shall establish a TRB and develop the necessary procedures to govern its operation. The manufacturer defines its own TRB structure. A manufacturer can have more than one TRB if appropriate. A manufacturer can have a TRB with ad-hoc members designated to represent non-essential functions on an as needed basis. For example, a representative from drilling will be assigned to the TRB as an ad-hoc member only attending meetings when the function requires representation. Written procedures which will govern the operation of the TRB shall be maintained and updated regularly. The manufacturer will be responsible for ensuring that the actions of the TRB result in printed boards that meet all customer and performance requirements. As a minimum, the TRB operating procedure shall address the following:

a. Minimum organizational membership (see A.4.1.1).

b. Duties and responsibilities (see A.4.1.2).

c. Traceability of data and records supporting TRB decisions.

d. TRB meeting structure, including agenda template, attendance list, and topics.

e. Decision making and approval procedures.

f. Distribution of TRB minutes.

A.4.1.1 Organizational structure. The manufacturer's TRB shall insure communication is established and maintained among representatives from conversion of customer requirements, technology development, fabrication, testing, quality assurance, and procurement (material and contract services) organizations. The TRB shall be a cross-functional technical group. Other personnel with decision making responsibilities affecting the product, its processes, or its production facility shall participate as required. The manufacturer shall identify those organizations that shall be represented on the TRB. A responsible technical representative within each of these organizations shall be identified to the qualifying activity. The members of the TRB shall have the responsibility and authority to make decisions and the resources to implement these decisions. Records of the TRB deliberations and decisions shall be maintained. These records shall be made available to the qualifying activity.

A.4.1.2 Duties and responsibilities.

A.4.1.2.1 TRB duties. The TRB duties are defined as follows:

a. Developing, implementing, maintaining the QM plan, and all supporting documents.

b. Developing, monitoring, maintaining, and controlling the QM program and all supporting documents, data and records.

c. Monitoring and controlling the self–assessment program.

d. Managing and maintaining the quality improvement programs, including setting measurable quality objectives, and monitoring their progress towards meeting those objectives.

e. Monitoring failures, customer returns, and complaints.

f. Maintaining records of conditions found and actions taken.

g. Addressing the impact of key managerial and TRB personnel changes and business plans in order to evaluate any impact they may have on the QM program.

h. Reporting periodically the status of the QM program, technology, and products to the qualifying activity (see A.4.6).

A.4.1.2.2 TRB responsibilities. The TRB shall oversee the manufacturer's qualified technology, including the materials and processes used. The TRB shall have a methodology in place for assessing and monitoring the quality of its' printed boards. The TRB shall be responsible for the following:

a. Approving all process flow charts and control plans for each individual process.

b. Overseeing and controlling all aspects of material and process changes.

c. Overseeing the initial material and process qualification and subsequent maintenance thereof.

d. Monitoring its processes and the performance of any contract services.

e. Approving all test optimizations that either modifies, substitutes, or deletes existing test methods or sampling for MIL–PRF–31032 specification sheet verifications (LCI, PCI, and CVI).

f. Reviewing and analyzing data (e.g., defect data, the rate of printed board or lot failure, rate of failure returns, and failure analysis results) and taking appropriate action to improve processes. When performance of shipped printed boards is called into question or indicates corrective action is required, the TRB shall provide quick evaluation, appropriate corrective action, and prompt notification of the problem to the qualifying activity to preserve the manufacturer’s qualified status and assure that defective printed boards are not shipped. In the event that suspect product was found to have been shipped, the TRB shall also provide prompt notification to any affected customer(s) and provide corrective action as to both the cause of the failure and the cause of the shipment of discrepant material.

g. Determining what test or verifications are needed to prove out material and process changes and custom technologies.

h. Verifying that only certified/qualified materials and processes are used in the production of QML printed boards.

A.4.2 Process flow (see 6.4.25). All processes in the flow shall be defined by documented procedures. The manufacturer’s process and verification procedures shall be in a language that is understood by the operator performing the given operation or verification.

A.4.2.1 Product manufacturing and testing flows. Manufacturers of compliant printed boards to an applicable specification sheet shall establish a baseline process flow detailing the material entry points, processes, process monitors, and the order in which processes or operations and verifications are performed. The process flow will be verified by the qualifying activity during the quality system audit. The process flow used to list a QML manufacturer can be one or more of its product manufacturing flows (e.g., travelers) that are representative of the manufacturer's processes and materials.

A.4.2.2 Rework. Rework operations shall be controlled, documented, and recorded in an equivalent manner to other processes.

A.4.3 Functional organization chart. This chart shall show the lines of authority and responsibility of any organization associated with the QM program, including the TRB, quality assurance, and production organizations (including names of TRB members).

A.4.4 Customer communication.

A.4.4.1 Conversion of customer requirements (see 6.4.10). The manufacturer's TRB shall establish the system for converting requirements in the printed board procurement documentation, the applicable specification sheet, orders, and contract requirements into the manufacturer's internal instructions and tools (in-house procedures, methods, travelers, and specifications). The conversion of customer requirements system shall interface with the document control system (see A.4.17), including the revision and distribution control, to assure that printed boards meet the specified requirements. The conversion of customer requirements system shall ensure the review of purchase requirements and modifications received from the customer. The review shall insure that the customer's requirements do not violate the applicable specification sheet for QML branding and that any special instructions in the printed board procurement documentation are accounted for. The conversion of customer requirements system shall provide objective evidence of this review. The conversion of customer requirements system shall address the following:

a. Printed board procurement documentation requirements.

b. The applicable specification sheet or custom technology (see 6.4.11) requirements.

c. Printed board design review procedures (established geometric, electrical, and design rules).

d. Phototool generation procedure (see A.4.4.2).

e. Testing capabilities.

f. Printed boards built in accordance with approved process flow (certification).

g. QML listing coverage (qualification).

h. Lot conformance inspection procedures.

i. Incoming inspection and vendor procurement documentation (see A.4.18).

j. Traveler.

k. Marking (see 3.8).

l. Rework (see A.4.2.2).

m. Printed board-to-test coupon correlation (see A.4.4.3).

A.4.4.2 Phototool or image database requirements (when applicable). The phototooling or image database used in the production of printed boards or panels shall conform to the requirements of the printed board procurement documentation.

A.4.4.2.1 Production master or image database. The acquiring activity is responsible for the accuracy of the production master or the information in the data base from which the production master or image is generated when either the production master or data base is provided to the printed board manufacturer. The printed board manufacturer shall insure that the finished printed board conforms to the specified printed board detail requirements (see 3.1.1).

A.4.4.2.2 Panelization requirements. The panel position of test coupons shall be as specified by the design standard specified by the printed board procurement documentation or TRB developed panel acceptance plan. Acquiring activity supplied phototooling not having the required number, proper placement of test coupons, or having test coupons that do not conform to design parameters shall be reprocessed or supplemented to correct any deficiencies.

A.4.4.3 Test coupons. Test coupons shall be evaluated for printed board representation during the conversion of customer requirements process.

A.4.4.3.1 Printed board-to-test coupon correlation. A method or procedure to verify correlation between test coupons and actual printed boards and panels shall be approved by the TRB. A documented correlation between the test coupon and the printed boards it represents shall be completed during conversion of customer's requirement to ensure proper printed board representation by the test coupon. This is necessary because of the printed boards variabilities introduced by test coupon location, design, and the panel processing.

A.4.4.3.2 Test coupon sampling. Selection of test coupons for inspection and testing shall be in accordance with either the applicable specification sheet or an approved TRB developed panel acceptance plan.

A.4.4.3.3 Acquiring activity requested test coupons. Acquiring activity requested test coupons (to be delivered with the shipment of printed boards) need to be added to the panel so as to increase total number of test coupons available; i.e., shall be in addition to the minimum requirements stated in the applicable specification sheet, and do not count to satisfy the minimum number needed to perform lot conformance inspection. Acquiring activity furnished test coupons (unique design parameters) may not be capable of verifying the performance requirements of the applicable specification sheet.

A.4.5 Manufacturer self–assessment.

A.4.5.1 Self-assessment system. The manufacturer's TRB shall have an independent self-assessment system to assess the effectiveness of the manufacturer's QM program. This self-assessment system shall identify any deficiencies for resolution concerning deviations from the QM plan, printed board procurement documentation, or specification sheet requirements. The manufacturer's TRB shall establish the procedures, frequency, and checklists used by the manufacturer to determine it's QM program compliance to their QM plan. The self–assessment system shall cover, as a minimum, all items in the QM plan.

A.4.5.2 Self-assessment representatives. The TRB authorized personnel, manufacturer's quality assurance representative, or their designated appointees shall perform all self-assessments. The representatives shall be independent from the areas reviewed.

A.4.5.3 Deficiencies. All deficiencies shall be identified and submitted to the areas department head for corrective actions. All corrective actions shall be agreed to by the TRB prior to implementation.

A.4.5.4 Follow up. The TRB shall establish a procedure to follow up on all deficiencies to assure the corrective actions have been implemented.

A.4.5.5 Schedules. The original self-assessment frequency shall be established by the manufacturer's TRB, but initially not exceed 12 months for each area unless authorized by the qualifying activity. Changes to the frequency of self-assessment shall require approval of the TRB.

A.4.5.6 Production process verification.

A.4.5.6.1 Process flow demonstration. Prior to the initial quality system audit by the qualifying activity, the proposed process flow and product verification program to be used for qualified products shall be demonstrated on sample lot or lots of printed boards. The printed boards can be either from normal production or the proposed qualification test vehicle(s). The process flow and verification program demonstration shall be performed on printed board sample units produced with equipment, materials, and procedures to be certified.

A.4.5.6.2 First piece produced (first article) inspection. The organization shall use a representative item from the first production run of a new design or assembly to verify that the production processes, production documentation, and equipment or tooling are capable of producing printed boards that meet the specified requirements. This process shall be repeated when changes occur that invalidate the original results (e.g., engineering changes, manufacturing process changes, equipment or tooling changes).

A.4.5.7 Self-assessment results. Records of the self-assessment audits and their results shall be maintained. The results of the self-assessment shall be made available to the qualifying activity prior to the quality system audit.

A.4.6 QML status. The manufacturer's TRB shall make available data to the qualifying activity describing the condition of the QML manufacturer's process flow. The information in the QML status summary may be addressed in various ways, such as, copies of TRB meeting minutes, summary of major actions, etc. The following areas shall be discussed and updated in each QML status:

a. Summary of TRB activity.

b. Self–assessment results.

c. Continuous improvement update.

d. Process control.

e. Corrective actions.

f. Fabrication facility.

g. Test facility.

h. QML compliant printed boards shipped, including QPL compliant printed boards produced under the certified QM plan (see 6.3.5, 6.5.1, and 6.5.2).

i. Customer returns.

j. Summary of inspection lot data, including part fallout and lot rejection.

k. The results of periodic conformance inspection and capability verification inspection assessment.

l. Summary of major and minor changes (see A.5).

m. Future business plans.

The frequency of the QML status summary sent to the qualifying activity will be agreed upon by the TRB and qualifying activity, but shall be as a minimum quarterly for the first year following the attainment of QML.

A.4.7 Continuous improvement. This plan shall document the specific procedures to be followed by the manufacturer to assure continuous improvement in quality, reliability of the process, and the printed boards being produced.

A.4.8 Failure analysis. This plan shall establish the procedures that a manufacturer self-imposes to test and analyze failed printed boards from all stages of manufacturing and customer returns. This plan shall also identify corrective actions or specify the use of a corrective action plan based on the findings of the failure analysis.

A.4.9 Process control. This plan shall establish the procedures that a manufacturer uses to control, monitor, and optimize its processes. This plan shall include goals and plans of implementation and measurement points (including location on applicable flow charts). This plan shall define how all processes are controlled, monitored, and optimized, including use of statistical tools, as applicable (see 4.5).

A.4.10 Corrective action. This plan shall specify the steps followed by the manufacturer to correct any problems or process that is out-of-control or found to be defective.

A.4.11 Qualification process procedure. The manufacturer shall establish a qualification process procedure which describes the qualification process and assigns responsibility for each activity. The procedure shall include as a minimum:

a. Development and documentation (i.e., drawings, travelers) of test vehicles.

b. Testing sequences, and conditions. Manufacturers of emerging technologies or advanced technologies shall also perform technology characterization (see 6.4.47) as part of the qualification process.

c. Sample sizes and selection.

d. Data recording and retention.

e. Use of extra test vehicles for spares.

f. Failure analysis and corrective action.

g. Resubmission criteria.

h. Reporting.

A.4.12 Periodic conformance inspection (see C.4). This plan shall be used as a tool for monitoring the quality and reliability of the manufacturer's technology, capabilities, materials, and processes. The plan shall describe how each base material type(s) qualified will be addressed, the minimum number of test vehicles to be used, the parameters to be measured, the frequency of measurement, the number of sample measurements, the methods of measurement, and the analysis of resulting data.

A.4.13 Training. The training and testing practices, employed to establish, evaluate, and maintain the skills of personnel engaged in production, testing, or inspection shall be documented as to form, content, and frequency. The manufacturer shall define training requirements which assure operator knowledge of internal standards and proficiency to perform assigned tasks. The methods of updating operators to changes in internal standards and to assure continued proficiency shall be addressed. Records showing the basis of operator acceptability shall be on file including instruction and evaluations received. Records are required only for product related training as distinguished from safety, first aid, etc.

A.4.14 Contract services. This plan shall specify how the manufacturer selects and monitors contract services. The plan shall describe what actions are to be taken to assure the contract service continually meets the QM plan requirements.

A.4.15 Test optimization (when applicable). This plan shall specify the steps the manufacturer will take to ensure compliance to appendix D.

A.4.16 Capability verification inspection (see C.5). This plan shall be used as a tool for periodically verifying the technology capability as listed on QML–31032. The plan shall describe how each qualified technology would be verified.

A.4.17 Document and data control.

A.4.17.1 Document control procedures. The manufacturer's TRB shall establish and maintain procedures to control all documents that relate to the requirements of this specification and applicable specification sheet. This includes, to the extent applicable, military and industry specifications and standards and their revisions, amendments, and notices. Data and records are documents and shall be controlled in accordance with A.4.17.3.

A.4.17.2 Document approval and issue. The TRB, or TRB authorized personnel, shall review and approve for adequacy documents prior to issue and use. The document control procedure shall ensure that the current issue of appropriate documents are available at all required locations, that invalid or obsolete documents are promptly removed from all points of issue, and that any obsolete documents which are retained are suitably identified. The TRB shall periodically review and either re-approve or update as necessary the controlled documents.

A.4.17.3 Quality data and records. The document control procedure shall define the controls needed for the identification, protection, retention time, retrieval, storage, and disposal of data and records. The data and records shall provide evidence of conformity to requirements and the effective operation of the QM program.

A.4.17.3.1 Records to be maintained. Records shall be legible and maintained which will adequately describe the processes, materials, inspections, and tests which affect the quality of the printed board for appropriate amounts of time such that quality concerns and customers are properly supported (e.g. conformance testing records). The records pertaining to production processes, incoming, and in-process inspections should be retained for a minimum of 3 years (7 years for space level) and those pertaining to performance verification retained for a minimum of 5 years (7 years for space level) after performance of the inspections. Records pertaining to alternate methods (with qualifying activity approval), conformance testing shall be retained for 5 years (7 years for space level) after the process or materials affected have been removed from the qualified flow.

A.4.17.3.2 Computerized records. Computerized records are optional provided they clearly and objectively indicate that all requirements of the specification sheet have been met. The computerized records for traceability, conformance inspection, and periodic inspection should be readily accessible and available to Government personnel for review and an appropriate electronic or hard copy provided to the qualifying activity as required. Computerized records, when used, should be maintained with controls sufficient to easily provide the necessary information and traceability, including identification of individual and time of input. The integrity of the system and the data should be maintained.

A.4.17.3.3 Altered records. Altered records should identify all information necessary to maintain proper traceability and the integrity of the original data and justification for the change.

A.4.18 Purchasing process. The TRB shall ensure that purchased material or services conforms to the specified purchase requirements. The type and extent of control applied to the supplier and the purchased material or service shall be dependent upon the effect of the purchased product or service has on the resulting printed boards. The TRB shall be responsible for the conformity of all materials or services purchased from suppliers, including materials or services from sources specified by the customer.

A.4.18.1 Incoming inspection. The TRB shall have in place procedures to insure conformance of purchased materials and products. Procedures shall be in place to insure conformance of the printed board material to the applicable printed board material acquisition documents or material specifications. Inspection reports, certificates of compliance, and test data shall be maintained on file for review by the qualifying activity.

A.4.18.2 Printed board material evaluation. Printed board material evaluation shall be successfully completed prior to use in the production of printed boards. Printed board material acquisition documents shall identify the printed board material characteristics required to assure printed board performance and fabrication or process capability.

A.4.18.3 Storage. The storage conditions (e.g., temperature, relative humidity, etc.) and length of storage time before reinspection of printed board materials used in compliant printed board fabrication shall be in accordance with the vendor or material suppliers recommended storage instructions. Expired materials shall be controlled in a similar manner to non-conforming materials.

A.5 CHANGE CONTROL

A.5.1 General. The change control plan shall describe the process by which a manufacturer monitors and addresses changes to the QML program and the certified and qualified technology.

A.5.1.1 Change assessment. All changes to any certified part of a printed board manufacturer's process flow are to be governed by the manufacturer's TRB and made available for review by the qualifying activity. All changes shall be documented as to the reason for the change with supporting data taken to justify the change, as appropriate. The decision as to the criticality of the change shall be guided by the potential effect of the change on quality and performance of the resulting printed boards. For any change that merits consideration for requalification, the TRB and qualifying activity shall decide if requalification is needed. Printed boards can be shipped following a change only upon approval of the TRB.

A.5.1.2 Classification of changes. Unless otherwise specified, changes shall be categorized into either major or minor changes. The classification of changes shall be as follows:

a. Major: Major changes are those changes that may affect the performance, quality, or reliability of the printed board. Major changes also include changes to the QM plan.

b. Minor: Minor changes are changes that do not affect performance or quality of the printed board, or are editorial in nature.

A.5.1.3 Change notification. Notification of major changes shall be made concurrently to the qualifying activity. A summary of all changes shall be made in the QML status (see A.4.6).

A.5.2 Change control concerns and considerations. The following paragraphs outline areas of concern where a change may require action by the printed board manufacturer. These lists provide examples and are not all-inclusive.

A.5.2.1 Fabrication change.

a. Fabrication process sequence or process limits.

b. Fabrication process materials and chemicals or material and chemical specifications.

c. Fabrication equipment or machines.

d. Printed board materials (base materials, metal foils, finishes, adhesives, etc.).

e. Process flow.

f. Physical relocation of fabrication equipment.

g. Addition of new fabrication.

h. The addition of, or change to, contract services for fabrication processes.

A.5.2.2 Test or inspection change.

a. Sample plans and lot formation.

b. Lot conformance inspection procedures including manufacturer imposed tests.

c. Periodic conformance inspection procedures including conformance inspection vehicle and how they are tested.

d. Test and inspection procedures.

e. Testing flow.

f. Test optimization.

A.5.2.3 Test facility change.

a. Physical relocation of test equipment.

b. Addition of, or change to, a new test facility or equipment.

A.5.2.4 Miscellaneous changes.

a. Key managerial (corporate and TRB) changes.

b. Business plans (mergers, new technologies).

c. Calibration procedures.

A.5.3 Document changes. Unless designated otherwise, changes to documents shall be reviewed and approved by the TRB or the TRB authorized functions, or organizations within the facility that performed the original review and approval.

A.6 NOTES

A.6.1 Notes. The adoption of a quality management program should be a strategic decision of a manufacturer. The design and implementation of a manufacturer's quality management program can be influenced by varying needs, particular objectives, the types of printed boards or technology provided, the processes employed, and the size and structure of the manufacturer. It is not the intent of this specification to imply uniformity in the documentation of, or the structure of, quality management programs. The requirements of this appendix can be used by internal and external parties to assess the manufacturer’s ability to meet the customer’s and the manufacturer's own requirements.

# APPENDIX B

# QUALIFICATION

## B.1 SCOPE

B.1.1 Scope. This appendix establishes general requirements applicable to initial qualification, custom technology qualifications, and the qualification of additions and changes to materials and processes. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

B.2 APPLICABLE DOCUMENTS This section is not applicable to this appendix.

## B.3 QUALIFICATION

B.3.1 General. All certified processes and materials shall be qualified. Qualification testing shall be performed on qualification test vehicles that will demonstrate the manufacturer's technology. The capabilities listed on the QML will be for those materials and processes that are actually tested and comply with the acceptance and performance requirements specified.

B.3.1.1 Qualification test plans. The manufacturer shall develop a specific test plan for each qualification. The qualification test plan shall be developed in accordance with the qualification process procedure (see A.4.11). The TRB approved qualification test plan shall be submitted to the qualifying activity for review and approval. Upon qualifying activity approval, the manufacturer shall proceed with any needed qualification testing. The qualification test plan shall state what design and manufacturing parameters that the qualification test vehicle represents. The plan shall include as a minimum:

a. The description of the test vehicle or vehicles (i.e., the master drawing or design detail and other information for each test vehicle).

b. The test sequence including conditions and sample size (requirement may be met with a test traveler).

c. The identification and location of test facilities.

d. A statement that the test vehicle will be built in accordance with the manufacturer's conversion of customer's requirements and certified process flow.

e. The proposed QML listing.

f. A summary matrix that compares each item in the proposed QML listing to each test vehicle. This summary shall show the relationship between the test vehicle(s) and the proposed QML listing.

B.3.1.2 Qualification test vehicles. The manufacturer shall produce qualification test vehicles using the certified process flow. The qualification test vehicles shall be manufactured in an actual production environment by trained personnel using approved methods and procedures with proper traceability records. The qualification test vehicles shall be of such complexity as to be representative of the technology to be supplied by the manufacturer.

B.3.2 Tests and inspections. Unless otherwise specified (see B.3.1.1), tests, test conditions, and sample sizes will be as specified in the applicable specification sheet for standard technologies, or as detailed in the QM plan for custom technologies. Additional or reduced testing, as may be dictated by the uniqueness of a particular technology or qualification requirements of the applicable specification sheet or custom technology, shall be authorized by the qualifying activity.

B.3.3 Qualification routines.

B.3.3.1 Initial qualification to a MIL–PRF–31032 specification sheet technology. Initial qualification to any standard technology shall demonstrate compliance to the MIL–PRF–31032 specification sheet or sheets. A qualification test plan will be approved by the qualifying activity at the time of certification.

B.3.3.2 Initial qualification of a custom technology. The manufacturer shall submit to the qualifying activity the process flow to be certified that lists any processes or materials used for the custom technology. Upon receiving qualifying activity certification approval, the manufacturer's TRB shall perform technology characterization to determine the technology capability and develop a qualification test plan for qualifying the custom technology.

B.3.3.3 Expansion of a qualified technology (add-on). When expanding or updating a qualification listing for a technology (either standard or custom) for increased capabilities, the manufacturer's TRB shall develop a qualification test plan that addresses the change, or changes, to the QML listing. The manufacturer may elect not to obtain a specific expansion of qualification test plan approval from the qualifying activity prior to qualification testing provided the qualifying activity has approved the qualification process procedure and the qualification test plan for that expansion has been approved by the manufacturer's TRB. After successful completion of the qualification tests, TRB review, and approval of the tests results; the printed boards from the lot may be certified complaint and shipped upon successful completion of LCI verifications. The qualifying activity shall be notified of the results of the expansion qualification so that the added capabilities, materials, processes, or technologies can be added to the manufacturer's QML listing. A copy of the expansion qualification test report shall be made available to the qualifying activity.

B.3.3.4 Qualification using existing data. When the manufacturer's TRB has existing data previously recorded for other purposes, a qualification test plan can be based on this data. The TRB shall perform a comprehensive analysis of the existing data and be able to demonstrate equivalence of all tests and inspections. The TRB shall be able to demonstrate to the qualifying activity that the technology represented by the existing data is capable of meeting the performance requirements outlined in the applicable specification sheet or the custom technology defined within the QM plan. The existing data and the results of the TRB review shall be made available to the qualifying activity upon request. The TRB shall notify the qualifying activity of the QML listing parameters for inclusion on QML–31032. Design, construction, materials, and process information shall also be submitted for inclusion in the qualification notification.

B.3.3.5 Discontinued technology. When a manufacturer has, or plans to, discontinued a specific process, material, or capability, the TRB shall notify the qualifying activity of the details regarding what certified and qualified technology(ies) has been, or will, be discontinued and an effective date of such action(s).

B.3.4 Qualification eligibility. Qualification is only possible once certification of a technology is granted by the qualifying activity.

B.3.4.1 Use of existing data and testing performed prior to certification. The test results or existing data from tests, or inspections, performed prior to certification can be used to justify the qualification of a certified material or process provided the test vehicles used are representative of the certified technology. The fabrication and testing of the qualification test vehicles may begin before certification is granted. However, if deficiencies and concerns found during the qualifying activity's quality system audit or off-site review requires changes to the process flows, fabrication, or tests and inspections routines, retesting may be necessary.

B.3.4.2 Procedure. If existing data is not available to gain QML listing, then the manufacturer shall begin production of the qualification test vehicle(s) upon receipt of certification. A qualification test plan will be approved by the qualifying activity at the time of certification.

B.3.4.3 Non-qualification of a certified technology. The TRB shall notify the qualifying activity of any decision not to pursue qualification of any technology previously certified.

B.3.5 Custom technologies qualifications. When a MIL–PRF–31032 specification sheet does not address or cover a technology, the TRB shall determine the technology capability and develop acceptability requirements, sampling plans, and the verifications necessary for the certification and qualification of the custom technology.

NOTE: A custom technology may include a technology that has heritage for the industry, but not for the manufacturer, or it may be a technology that is totally new to the industry.

B.3.6 Qualification failures.

B.3.6.1 Resubmission of failed samples or lots (or both). Unless otherwise specified, resubmission of failed samples or additional samples from the same production lot are not allowed unless such failures are due to equipment or operator errors. Notification of the qualifying activity is required.

B.3.6.2 Corrective actions. If any sample fails a test or inspection, the manufacturer shall perform failure analysis, take necessary corrective action, and adjust the process until new samples pass all tests and inspections. Notification of such adjustments or changes shall be given to the qualifying activity in a timely manner (see A.5).

B.3.7 Qualification test summary and data. The TRB shall present to the qualifying activity a test summary that includes a comprehensive analysis of the qualification data. The aim of this analysis is to show that the manufacturer is capable of producing the technology. Detailed limits and conditions for each verification method used shall be clearly identified and recorded. Test vehicles used for destructive tests should be presented to the qualifying activity with the testing summary. The following data shall be retained by the manufacturer, with copies supplied to the qualifying activity, to support the results:

a. Production and test travelers for all test vehicles.

b. Results from each subgroup test conducted, both initial and any resubmissions. This shall include results of all internal and external laboratory testing and inspection, in accordance with the qualification test plan

c. Number of qualification test vehicles tested and rejected.

d. Failure mode and mechanism for each rejected qualification test vehicle.

e. Read and record variable data on all specified dimensional or electrical parameter measurements.

f. A copy of the qualification test plan.

B.3.8 Qualification by similarity. Upon approval of the qualification test report by the qualifying activity, printed boards that are fabricated with the same materials, processes, and within the process parameters and capability window defined in the MIL–PRF–31032 specification sheet shall be considered qualified by similarity.

B.3.9 Data retention. All records that support the results of qualification testing (production travelers and test data or results, including failure analysis, if applicable) shall be retained in accordance with the requirements of 3.9 herein.

APPENDIX B

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# APPENDIX C

# CONFORMANCE INSPECTION

## C.1 SCOPE

C.1.1 Scope. This appendix establishes general requirements applicable to conformance inspection. Conformance inspection covers lot conformance inspection, periodic conformance inspection, and capability verification inspection. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

## C.2 APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

## C.3 LOT CONFORMANCE INSPECTION

C.3.1 Lot conformance inspection. Lot conformance inspection (LCI) testing shall be performed by the manufacturer on each inspection lot to assure that the printed boards meet the requirements of the applicable specification sheet and printed board procurement documentation. Printed boards shall not be accepted or approved for delivery until all applicable performance requirements have been verified.

C.3.2 Percent defective allowable (PDA). When the total number of failed/rejected printed boards or panels from an inspection lot for a specific defect exceeds the specified percent defective allowable limit for that particular test routine, subgroup or inspection, then the entire inspection lot shall be rejected.

C.3.2.1 Rejected lots. Once an inspection lot has been rejected, the panels or printed boards shall be evaluated and corrective action, approved by the TRB, shall be taken. Any panels or printed boards further determined as failures shall not be shipped as compliant printed boards. Traceability history shall reflect actions taken to printed boards or justification, if any, of the printed boards that are shipped.

C.3.3 Panel acceptance. The tests to be performed for panel acceptance shall be as specified in the applicable specification sheet.

C.3.3.1 Failures. Any test coupon that fails any panel acceptance requirements shall result in the printed boards represented by that test coupon to be removed from the lot.

C.3.4 100 percent inspections. The tests to be performed for 100-percent inspection shall be as specified in the applicable specification sheet.

C.3.4.1 Failures. Printed boards or test coupons that fail to meet the requirements of any of the tests listed in the 100-percent inspections of the applicable specification sheet, shall be removed from the lot and considered as non-compliant.

C.3.5 Sample test inspections. The tests to be performed for sample inspection shall be as specified in the applicable specification sheet.

C.3.5.1 Sampling. Samples shall be randomly selected from the entire inspection lot. The number of printed boards or test coupons to be tested or inspected shall in accordance with the applicable requirements of appendix E.

C.3.5.2 Rejected lots. If an inspection lot is rejected, the manufacturer may screen out the defective units and resubmit the lot for re–inspection. Printed boards that are screened out due to failure to meet the requirements of any of the tests listed in the sample inspections subgroup of the applicable specification sheet, shall be removed from the lot and considered as non-compliant.

C.3.5.3 Resubmission of rejected lots. Resubmitted lots shall be kept separate from new lots and shall be clearly identified as resubmitted lots. When any lot submitted for lot conformance inspection fails any subgroup requirement, it may be resubmitted once for that particular subgroup using tightened inspection criteria as defined in appendix E. A second resubmission using tightened inspection criteria is permitted only if failure analysis is performed to determine the failure mechanism for each failed printed board from the prior submissions and it is determined that the failure is due to:

a. A defect that can be effectively removed by an additional 100-percent inspection or test of the entire lot.

b. Random type defects which do not reflect printed board design or processing procedures.

In all instances where failure analysis of the failed printed boards indicates that the failure mechanism is due to processing procedures, a design fault or nonscreenable defects, the lot shall not be resubmitted.

C.4 PERIODIC CONFORMANCE INSPECTION

C.4.1 Periodic conformance inspection. Periodic conformance inspection (PCI) shall be accomplished by the manufacturer as defined in the applicable specification sheet. A manufacturer's normal production tests, environmental tests, and so forth, may be used to fulfill all or part of periodic conformance inspection specified in the applicable specification sheet.

C.4.2 Periodic conformance inspection program. Periodic conformance inspection or alternate assessment program shall be implemented by the manufacturer for each base material type qualified. The periodic conformance inspection program shall be designed to be used for the purposes of quality monitoring and change control evaluation. The periodic conformance inspection program shall address the following concerns:

a. General. The periodic conformance inspection program shall indicate what the conformance inspection vehicles are, where they are located, and how they are tested and analyzed. The processes or operations to be monitored shall be determined by the manufacturer based on its experience and knowledge of its processes. The criteria for evaluating conformance inspection vehicle(s) shall be determined by the TRB based on the manufacturer's assessment of risk.

b. Frequency. The TRB shall determine when such periodic conformance inspection shall be performed for each base material type(s) qualified. If the TRB does not specify a frequency of test within the periodic conformance inspection program, then the frequency specified in the applicable specification sheet shall apply.

c. Methods. The periodic conformance inspection program can use various test vehicles, methods, and measurement techniques listed in the applicable specification sheet.

d. Data and results. Periodic conformance inspection data, including failure analysis results, shall be available for review by the qualifying activity or quality system audit team.

e. Failures. Periodic conformance inspection failures do not automatically fail or disqualify a lot of printed boards when trends or limits require corrective action; however, failure analysis shall be performed on all failed conformance inspection vehicle(s) and actions taken to correct any problems found. The TRB shall notify the qualifying activity within 3 working days of discovery of the failure.

C.4.3 Conformance inspection vehicle. Conformance inspection vehicle(s), used for the periodic conformance inspection program, are designed for their role as a quality and reliability monitoring vehicle. The conformance inspection vehicle can be incorporated into the panel as a dedicated test coupon, be within a printed board, exist as a separate test vehicle, or any combination thereof. The conformance inspection vehicle(s) shall comply with the following requirements:

a. Documentation. Documentation procedures for conformance inspection vehicle(s) shall be the same as for production printed boards. Documentation of the conformance inspection vehicle(s) shall also include the design, design rules, test procedures and process rules.

b. Complexity. The complexity of the conformance inspection vehicle shall reflect, as a minimum, the functionality of the process and technology characteristics.

c. Design. The conformance inspection vehicle shall exercise the worst-case design rules. The conformance inspection vehicle shall be designed to stress the applicable geometric, electrical, or mechanical design rules. The electrical and mechanical stress requirements for interconnects shall be worst case conditions. The architecture of the conformance inspection vehicle shall be designed so that failures can be easily diagnosed.

d. Quantity and location. The number of conformance inspection vehicle(s) required and their locations (panel, printed board, or test vehicle) shall be as specified in the QM plan.

NOTE: Different conformance inspection vehicle(s) may be required whenever the technology, materials, design rules, processes, or the basic functionality of the technology differs.

C.4.4 Disposition of conformance inspection vehicle. Conformance inspection vehicle(s) which have been subjected to periodic conformance inspection shall be retained for the time period specified in the approved QM plan.

C.5 CAPABILITY VERIFICATION INSPECTION

C.5.1 Capability verification inspection. Capability verification inspection (CVI) shall be accomplished by the manufacturer as defined in the applicable MIL–PRF–31032 specification sheet and herein. Capability verification inspection shall be used to validate, on a regular basis, that the qualified materials and processes continue to conform to the originally qualified capabilities. A manufacturer's normal production tests, environmental tests, and so forth, may be used to fulfill all or part of capability verification inspection.

C.5.2 Capability verification inspection program. Capability verification inspection or alternate assessment program shall be implemented by the manufacturer for each base material type qualified. The capability verification inspection program shall be designed to be used for the purpose of verifying current qualification capabilities as listed on QML–31032. The capability verification inspection program shall address the following concerns:

a. General. The capability verification inspection program shall indicate the type (i.e. chemical, physical, environmental) of tests and inspections that will be used to verify current capabilities, including what the conformance inspection vehicles are and where they are located. The criteria for evaluating conformance inspection vehicles shall be determined by the TRB based on the manufacturer's assessment of risk.

b. Frequency. Capability verification inspection shall be performed for each base material type qualified using the frequencies established in the applicable MIL–PRF–31032 specification sheet.

c. Methods. The capability verification inspection program can use various test vehicles, methods, and measurement techniques listed in the applicable MIL–PRF–31032 specification sheet. Also, the use of existing test data may be used in lieu of performing certain tests and inspections as defined in the approved QM plan.

d. Data and report. Capability verification inspection data, including failure analysis results, shall be compiled for TRB review and approval, and then forwarded to the qualifying activity for review to determine whether capabilities on QML–31032 should be continued, adjusted, or removed.

e. Failures. Capability verification inspection failures do not automatically fail or disqualify a lot of printed boards produced during the CVI period when trends or limits require corrective action; however, failure analysis shall be performed on all failed conformance inspection vehicles and actions taken to correct any problems found. The TRB shall notify the qualifying activity and affected customers within three working days of discovery of the failure.

C.5.3 Conformance inspection vehicle. The conformance inspection vehicles to be used for the capability verification inspection program shall be designed for their role as a quality and reliability monitoring vehicle. The conformance inspection vehicle can be incorporated into the panel as a dedicated test coupon, be within a printed board, exist as a separate test vehicle, or any combination thereof. All conformance inspection vehicles used for capability verification inspection shall comply with the following requirements:

a. Documentation. Documentation procedures for conformance inspection vehicle(s) shall be the same as for production printed boards. Documentation of the conformance inspection vehicle(s) shall also include the design, design rules, test procedures and process rules.

b. Complexity. The complexity of the conformance inspection vehicle shall reflect, as a minimum, the functionality of the process and technology characteristics.

c. Design. The conformance inspection vehicle shall exercise the worst-case design rules. The conformance inspection vehicle shall be designed to stress the applicable geometric, electrical, or mechanical design rules. The electrical and mechanical stress requirements for interconnects shall be worst case conditions. The architecture of the conformance inspection vehicle shall be designed so that failures can be easily diagnosed. All qualified plated hole constructions shall be represented.

d. Quantity and location. The number of conformance inspection vehicle(s) required and their locations (panel, printed board, or test vehicle) shall be as specified in the QM plan.

NOTE: Different conformance inspection vehicles may be required whenever the technology, materials, design rules, processes, or the basic functionality of the technology differs.

C.5.4 Disposition of conformance inspection vehicle. Conformance inspection vehicles which have been subjected to capability verification inspection shall be retained for the time period specified in the approved QM plan.

C.5.5 Non–production. If, at any time, there is a shortage of compliant printed boards available for processing at the QML facility, the TRB shall determine whether the processing of noncompliant printed boards sustains the capability to produce the technology. The TRB shall determine what activities and steps need to be taken to assure that a controlled process is still capable to produce compliant printed boards when required. Failure to maintain or monitor the QM program during compliant printed board production lulls, may be grounds for QML removal.

# APPENDIX D

# TEST OPTIMIZATION

## D.1 SCOPE

D.1.1 Scope. This appendix provides guidelines on test optimization. This appendix is not a mandatory part of the specification. The information contained herein is intended for guidance only. However, manufacturers wanting to use test optimization must be able to demonstrate an assessment system that achieves at least the same level of quality and reliability as could be achieved by complying with the guidelines in this appendix. Process monitoring and controls, statistical tools, and accumulated data may be used to prove the validity of test optimization.

## D.2 APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

## D.3 TEST OPTIMIZATION

D.3.1 Methods of test optimization. Test optimization includes the alternative methods listed below.

a. Reduction of testing/sampling. This includes reduction in the number of samples or test frequency, whether it is within a lot or periodic sampling.

b. Modification of tests. This includes using alternate test procedures, equipment, or test vehicles to achieve the same evaluation as the baseline verification method.

c. Moved tests. This pertains to performing tests in-process instead of after all processing is complete.

d. Elimination of tests. The tests are no longer performed.

D.3.2 Program requirements. Changes in a manufacturer's baseline test plan to include test optimization are considered major changes. The manufacturer is expected to maintain the established process control and evaluate the effect on quality and reliability of any out-of-control conditions that may exist at critical process parameters. If a process changes, the manufacturer should be prepared to reassess test optimizations currently in place to determine if they are still valid and effective. The manufacturer should also evaluate if a relationship exists between any processes used to optimize test and any customer returns or failure trends, take appropriate corrective actions, and record this information for future reference. As a part of the QML philosophy and conversion of customer requirements provision, the manufacturer should communicate variations in tests with customers, as appropriate or when requested. This information should be accessible via the manufacturer's QM program and should be made available to the qualifying activity.

D.3.3 Conditions of test optimization. Regardless of testing modifications, the manufacturer should supply printed boards capable of passing any test prescribed in the applicable specification sheet. Long term quality and reliability of printed boards should remain unaffected or be improved.

D.3.4 Critical process parameters. When deciding whether to eliminate a test, the following should be considered, as a minimum:

a. Variables critical to test outcome, called critical process parameters, should be identified and are in-control in accordance with the process control plan.

b. Assignable causes are understood and controlled at critical process parameters.

c. Critical process parameters have exhibited sufficient capability to assure low printed board defect rates.

D.3.5 Correlation, confirmation, and implementation procedures. The manufacturer should develop and document methods for confirmation and maintenance of process material capability. Test method requirements of MIL–PRF–31032 specification sheets are intended to address worst case application environments for military grade product. Any test optimization used in lieu of required testing should be approved by the manufacturer's TRB and the qualifying activity and should document the specific areas of correlation between the alternate method and the applicable specification sheet requirement it replaces. The following is a typical flow:

a. Identify candidate requirements of the applicable specification sheet for test optimization.

b. Using data, identify any correlations between the candidate requirements and the potential alternate method(s).

c. Where correlation exists, develop and document alternative method(s).

d. Accumulate data off-line to confirm the capability of the test optimization to assure that the requirements are met.

e. Submit test optimization for TRB approval.

f. Submit test optimization for qualifying activity approval.

g. Implement the test optimization.

D.3.6 Periodic assessment of test optimization. Test optimization should be periodically assessed, (determined and documented by the TRB), in order to assure its continued effectiveness. This periodic assessment is a tool for the TRB to aid in monitoring and maintaining product quality. Methods for periodic assessment may include stress-to-failure tests, failure mode analysis, analytic prediction modeling, etc. If test optimization is determined to no longer meet the initial requirements, the manufacturer should implement the appropriate baseline testing step previously approved by the TRB.

D.3.7 Measurements and retention requirements. Measurements taken for out-of-control conditions along with corrective actions should be recorded and this data should be maintained for a time period consistent with the lot conformance inspection data retention requirements stated in the QM plan. Data collected to prove the feasibility of the test optimization should also be maintained for the specified retention period, but it is recommended this data be retained for the life of the test optimization.

D.4 NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

D.4.1 Supporting documents. The documents in this section may be used as guidelines for the development of a test optimization program and are not mandatory for this specification.

TECHAMERICA

EIA–557 – Statistical Process Control Systems.

(Copies of this document can be obtained through the TechAmerica, 601 Pennsylvania Avenue, NW, North Building, Suite 600, Washington, DC 20004 or ordered online at URL http://www.techamerica.org.)

APPENDIX D

IPC – ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES (IPC)

IPC–9191 – General Guidelines for Implementation of Statistical Process Control (SPC).

(Copies of this document can be obtained through the IPC – Association Connecting Electronics Industries, 3000 Lakeside Drive, Suite 309 S, Bannockburn, IL 60015–1249 or ordered online at URL http://www.ipc.org.)

D.4.2 Notes. Although IPC–9191 and EIA–557 are not directly referenced herein, they may be used as guidelines to assist the manufacturer in the implementation of its test optimization program.

D.4.3 Discussion. The manufacturer may modify, substitute, or delete the test and inspections defined in the applicable specification sheet. This is accomplished by baselining a flow of test and inspections that will assure that the printed boards are capable of meeting the generic verifications provided in the applicable specification sheet. This does not necessarily mean that compliant printed boards have been subjected to the generic performance verifications provided in the applicable specification sheet, just that complaint printed boards are capable of meeting them. It is the TRB's responsibility to insure that their printed boards are capable of meeting the performance requirements applicable to each specific printed board technology.

APPENDIX D

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# APPENDIX E

# STATISTICAL SAMPLING, TEST, AND INSPECTION PROCEDURES

## E.1 SCOPE

E.1.1 Scope. This appendix details the statistical sampling, test and inspection procedures to be used with this specification and any MIL–PRF–31032 specification sheet. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

## E.2 APPLICABLE DOCUMENTS

E.2.1 General. The documents listed in this section are specified in sections E.5 and E.6 of this appendix. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirement documents cited in sections E.5 and E.6 of this appendix, whether or not they are listed.

E.2.2 Non–Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL (ASTM)

ASTM E29 – Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.

(Application for copies should be addressed to the ASTM International, 100 Barr Harbor Drive, P. O. Box C700, West Conshohocken, PA 19428–2959 or URL http://www.astm.org.)

IPC – ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES (IPC)

IPC–QL–653 – Certification of Facilities that Inspect/Test Printed Boards, Components and Materials.

(Application for copies should be addressed to IPC – Association Connecting Electronics Industries, 3000 Lakeside Drive, Suite 309 S, Bannockburn, IL 60015–1249 or URL http://www.ipc.org.)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.

(Application for copies should be addressed to the International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case Postale 56, CH–1211 Geneva 20, Switzerland or at URL http://www.iso.org.)

NCSL INTERNATIONAL (NCSL)

NCSL Z540–3 – Requirements for the Calibration of Measuring and Test Equipment.

(Copies of this document can be obtained through the NCSL International, 2995 Wilderness Place, Suite 107, Boulder, CO 80301–5404 or can be ordered online at URL http://www.ncsli.org.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

E.2.3 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein (except for related applicable specification sheet, the text of this document take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

E.3 DEFINITIONS AND SYMBOLS

E.3.1 Definitions. The following definitions shall apply for all statistical sampling procedures:

a. C = 0 sample plan: The C = 0 sample plans are defined as a combination of a test specimen usage identifier (see E.3.1.b herein) and a sample size series (see E.3.1.c herein). The resulting C = 0 sample plan will be a two character designator that identifies the sample size series that is to be used with a type of test specimen for a particular verification (see E.4.5).

b. Test specimen identifier: The following modifiers are used to differentiate when a particular sample size series is to be used for a particular test specimen: (B) shall be used to identify production printed boards, (T) shall be used for test coupons and an asterisk (*) for either printed boards or test coupons.

c. Sample size series: The sample size series is defined as the following series of letters: B, D, F, H, J, L, and N that are listed in table E–I.

d. Tightened inspection: Tightened inspection is defined as sampling using an increased sample size (see E.4.3).

e. Acceptance number (C): The acceptance number is defined as an integral number associated with the selected sample size which determines the maximum number of defectives permitted for that sample size.

f. Rejection number (R): Rejection number is defined as one plus the acceptance number.

E.3.2 Symbols. The following symbols shall apply for all statistical sampling procedures:

a. C: Acceptance number.

b. R: Rejection number.

E.4 STATISTICAL SAMPLING PROCEDURES AND SAMPLE SIZE SERIES TABLE

E.4.1 General. Statistical sampling shall be conducted using the C = 0 method. The C = 0 method as specified herein is a sampling plan that provides a high degree of assurance that a lot having a proportion defective greater than the specified acceptance number (C = 0) will not be accepted. For all situations, the acceptance number (C) shall be equal to 0 (C = 0) and the rejection number (R) shall be 1 or greater (R ≥ 1). For re-evaluation purposes, tighten inspection shall be used (see E.4.3).

E.4.2 Acceptance and procedure.

E.4.2.1 Acceptance number (C = 0). Lot acceptance shall be based on an acceptance number of zero (C = 0).

E.4.2.2 Rejection number (R ≥ 1). Failure of a sample unit for one or more tests of a subgroup shall be charged as a single failure. One or more sample rejects shall be cause for failure of the lot or sublot, as applicable. Any failure on any of the sample units shall constitute a failure of the entire inspection lot or sublot.

E.4.3 Tightened inspection. Tightened inspection shall be performed using one of the following:

a. Using the sample size series to the left of the specified sample size series (example, if series "J" was specified, then use series "H").

b. Doubling the sample size in the specified sample series.

c. One hundred percent inspection with zero failures allowed.

E.4.4 Sample size. The sample size for each subgroup shall be determined from table E–I. If lot size is smaller than sample size, test all of the units. The manufacturer may, at their option, select a sample size greater than that required; however, the number of failures permitted shall not exceed the acceptance number.

E.4.5 C = 0 sample plan construction (selection and usage of the sample size series). The sample size series of table E–I to be used will be specified by the MIL–PRF–31032 specification sheet. The MIL–PRF–31032 specification sheet will specify the C = 0 sample plan (test specimen identifier and sample size series) or plans (test printed board, test coupons, or either) when different test specimens can be used to perform a verification.

Examples: If a MIL–PRF–31032 specification sheet specified that "Plan BF or TL" be used when verifying test specimens, it is specifying that sample size series "F" of table E–I shall be used for selecting printed boards and sample size series "L" shall be used for selecting test coupons. If the same MIL–PRF–31032 specification sheet specified that "Plan *H" be used, then sample size series "H" of table E–I can be used for either printed boards or test coupons.

TABLE E–I. C = 0 (zero defect) sample size series.

| Lot size | Sample size (number of test specimens to be inspected) 1/ | | | | | | |
|---|---|---|---|---|---|---|---|
| | Series B | Series D | Series F | Series H | Series J | Series L | Series N |
| 1 to 8 | All | All | All | 5 | 3 | 2 | 1 |
| 9 to 15 | All | All | 13 | 5 | 3 | 2 | 1 |
| 16 to 25 | All | All | 13 | 5 | 3 | 2 | 1 |
| 26 to 50 | All | 32 | 13 | 5 | 5 | 3 | 2 |
| 51 to 90 | 50 | 32 | 13 | 7 | 6 | 4 | 2 |
| 91 to 150 | 50 | 32 | 13 | 11 | 7 | 5 | 2 |
| 151 to 280 | 50 | 32 | 20 | 13 | 10 | 6 | 4 |
| 281 to 500 | 50 | 48 | 29 | 16 | 11 | 7 | 4 |
| 501 to 1,200 | 75 | 73 | 34 | 19 | 15 | 8 | 4 |
| 1,201 to 3,200 | 116 | 73 | 42 | 23 | 18 | 9 | 4 |

1/ If lot size is smaller than sample size test all (100 percent) of the units.

APPENDIX E

E.5 MEASUREMENTS, TEST EQUIPMENT, CALIBRATION, AND INSPECTION FACILITIES

E.5.1 Control and monitoring of measurement and test equipment. All tests and measurements for process control, qualification testing, lot conformance inspection, periodic conformance inspection, or capability verification inspection shall be made with capable measurement instruments and test equipment whose accuracy has been verified. Calibration of measurement instruments, test equipment, and test standards that control the accuracy of inspection and test equipment and facilities shall be in accordance with NCSL Z540–3, or an equivalent system, approved by the qualifying activity. Calibrated measurement instruments, test equipment, and test standards shall be controlled, used, and stored in a manner suitable to protect calibration integrity. Test equipment requiring calibration shall be identified and labeled in accordance with NCSL Z540–3, or an equivalent system, approved by the qualifying activity. In accordance with the QM plan, stated reliability goals, test accuracy ratios, test uncertainty ratios, and significant-out-of-tolerance condition criteria shall be established.

a. The calibration interval analysis methodology used to maintain the measurement reliability of measurement instruments and test equipment shall have a stated reliability goal to meet a minimum 95 percent measurement reliability target for measurement instruments and test equipment in-tolerance at the end of their interval schedule.

b. Test optimization of test accuracy ratios as low as 4 to 1 shall be acceptable. However, the use of measurement instruments and test equipment with a test accuracy ratio that is less than 4 to 1 shall require a detailed measurement uncertainty analysis.

c. Significant-out-of-tolerance conditions are defined as any measurement and test equipment out-of-tolerance condition exceeding 25 percent of the specified tolerance. These conditions require documented review of impact on quality and notification of the qualifying activity.

E.5.1.1 Resolution of measurement devices and test equipment capability. Unless otherwise specified (see 3.1.1) or addressed by the TRB in the QM plan, the resolution of measurement devices and test equipment used for the evaluation of printed board performance shall be at least a factor of 10 better than the limits or tolerances of a value to be determined. For example: A voltmeter would need a resolution of ±0.1 percent to determine a tolerance of ±1 percent.

NOTE: State of the art requirements in which a 10:1 ratio cannot be effectively achieved due to a lack of national standards shall be justified and documented.

E.5.1.2 Electrical test frequency. When specified (see 3.1.1), the frequency of the electrical test shall be the specified operating frequency of the printed board. Where a frequency range is specified, major functional parameters shall be tested at the maximum and minimum frequencies of the range in addition to those tests conducted at any specified frequency within the range. Whenever electrical tests are conducted on printed boards for which a range of frequencies, or more than a single operating frequency is specified, the frequency at which tests are conducted shall be recorded along with the parameters measured at those frequencies.

E.5.2 Test methods.

E.5.2.1 Acquiring activity or manufacturer imposed tests. Acquiring activity or manufacturer imposed tests shall be in accordance with the requirements specified in the printed board procurement documentation or approved QM plan. If any additional imposed tests detect a problem, the manufacturer shall submit all panels/printed boards in the lot to those tests to eliminate rejects and shall take steps to determine and eliminate the cause of failure.

E.5.2.2 Test method alternatives or variations. Alternate test methods, or variation from the specified test method, are allowed provided that it is demonstrated to the qualifying activity, or their agent, that such alternatives or variations in no way relax the requirements of the test method referenced by the applicable specification sheet (see appendix D). Alternate test methods, or variation from the specified test method, shall be approved by the TRB, qualifying activity, or their agent before testing is performed. For proposed test variations, a test method comparative error analysis shall be made available for checking by the TRB, qualifying activity, or their agent.

E.5.2.3 Procedure in case of test equipment malfunction or operator error. When it has been established that a improper test is due to test equipment malfunction or operator error, the TRB or inspection facility shall document the results of its investigations and corrective actions, if required, and shall make this information available to the qualifying activity and the acquiring activity, as applicable.

E.5.3 Numeric reporting. The results of printed board verification shall be presented in accordance with the requirements outlined herein.

E.5.3.1 Observed values (true and nominal). The specification limit requirements specified are for true values. Nominal values are indicated by the inclusion of a tolerance. Proper allowance shall be made for measurement errors (including those due to deviations from nominal test conditions) in establishing the working limits to be used for the values to be measured, so that the values of the test specimen parameters (as they would be under nominal test conditions) can be determined properly.

E.5.3.2 Significant digits. Unless otherwise specified (see 3.1.1), the significant digits to be retained of an observed value shall be in accordance with the resolution requirements of E.5.1.1.

E.5.3.3 Rounding method. For purposes of determining conformance with the specification sheet limit, an observed value, or a calculated value, shall be rounded "to the nearest unit" in the last right-hand significant digit to be retained in expressing the specification limit, in accordance with the rounding method of ASTM E29. The significant digits to be retained of an observed value or calculated value shall reflect the resolution requirements of E.5.1.1.

E.5.4 Control based on uncertainty. Test processes that have complex characteristics are best performed and controlled by the application of uncertainty analysis. The overall uncertainty in a test or measurement process shall be determined and the impact of said uncertainty on the product parameter tolerance shall be taken into account. The methods used for determining uncertainty shall be defined and documented. The method selected shall use any or all combinations of the following forms:

a. Arithmetic addition (linear), normally produces an overly conservative estimate and reflects a highly improbable situation in which contributing errors are at their maximum limit at the same time and same direction.

b. Root sum square (RSS), normally applied where the errors tend to fit a normal distribution (gaussian) and are from independent sources.

c. Partial derivatives, used where complex relationships exist.

d. Monte Carlo simulation, used in very complex situations where other methods are not easily applied or do not fit.

e. Standard reference material (or controlled correlation device) testing providing observable data. NOTE: Observable data from a controlled device may be relied upon to provide feedback that confirms process performance is within statistical limits.

f. Analysis of systematic and random errors, applying corrections as applicable.

g. Any other recognized method of combining errors into an expression of uncertainty substantiated by an engineering analysis.

E.6 SUITABILITY OF INSPECTION FACILITIES

E.6.1 Suitability of inspection facilities. The inspection facility used to perform qualification testing, periodic conformance inspection, or capability verification inspection shall be certified by the qualifying activity to the requirements of ISO 17025, IPC–QL–653, or an equivalent system approved by the qualifying activity. Additional details regarding the suitability status of an inspection facility are outlined in the DLA Land and Maritime publication "Laboratory Suitability Information" that can be downloaded or viewed at the following URL: http://www.landandmaritime.dla.mil/Downloads.

E.7 DEFINITIONS FOR TEST EQUIPMENT AND INSPECTION FACILITIES

E.7.1 Accuracy. A measure of the closeness of an individual measurement or the average of a number of measurements to the true value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations.

E.7.2 Bias. The systematic or persistent distortion of a measurement process, which causes errors in one direction (i.e., the expected sample measurement is different from the sample's true value).

E.7.3 Calibration. Calibration is an activity related to measurement and test equipment. Calibration is the comparison of measurement standard, instrument, or item of known precision and bias with another standard, instrument, or item to detect, correlate, report, or eliminate by adjustment, any variation in the precision and bias of the item being compared. Use of calibrated measurement standard, instrument, or items provide the basis for value traceability of product technical specifications to national standard values.

E.7.4 Limit or specification limit. A specification limit are numerical requirements specified in an applicable specification sheet, in the applicable master drawing, or in referenced documents, for the minimum or maximum value used for acceptance purposes.

E.7.5 Measurement and testing equipment. Tools, gauges, instruments, sampling devices, or systems used to calibrate, measure, test, or inspect in order to control or acquire data to verify conformance to specified requirements.

E.7.6 Precision. The degree to which a measurement standard, instrument, item, test, or process exhibits repeatability. Expressed statistically or through various techniques of Statistical Process Control (SPC), the term is many times used interchangeably with "repeatability". Precision is a measurement of how closely the analytical results can be duplicated.

E.7.7 Resolution. The smallest unit of readability or indication of known value on an instrument, device, or assemblage thereof. It is also related to the gradations on measuring instruments and the ability of the inspection/test personnel to interpret between those gradations. The resolution value is frequently used in the device literature to classify the instrument.

E.7.8 Standard reference material (SRM). A device or artifact recognized and listed by the National Institute of Standards and Technology (NIST) as having known stability and characterization. SRMs used in product testing provide traceability for technical specifications. SRMs do not require calibration when used and stored in accordance with NIST accompanying instructions. They are used as "certified materials".

E.7.9 Test Accuracy Ratio (TAR). A TAR is a ratio that uses only the accuracy of the instrument(s)

E.7.10 Test Uncertainty Ratio (TUR). A TUR is a ratio that includes all pertinent measurement process uncertainties.

E.7.11 Tolerance. The total amount by which a specific dimension is permitted to vary. A tolerance is indicated in this specification only if it is expressed as the variation about a specified value (also known as a "nominal value").

E.7.12 Uncertainty. An expression of the combined errors in a test measurement process. Stated as a range within which the subject quantity is expected to lie. Comprised of many components including estimates of statistical distribution and results of measurement or engineering analysis. Uncertainty established with a suitable degree of confidence, may be used in assuring or determining product conformance and technical specifications.

E.8 NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

E.8.1 Supporting document. The document in this section may be used in understanding how the sample size series of table E–I were derived and developed.

TECHAMERICA

EIA–585 – Zero Acceptance Number Sampling Procedures and Tables for Inspection by Attributes of Isolated Lots.

(Copies of this document can be obtained through the TechAmerica, 2500 Wilson Boulevard, Arlington, VA 22201–3834 or ordered online at URL http://www.techamerica.org.)

E.8.2 Documents regarding uncertainty. The documents in this section may be used as guidelines in understanding measurement and test assurance principals.

ASME INTERNATIONAL (ASME)

ASME B89.7.3.1 – Guidelines For Decision Rules: Considering Measurement Uncertainty In Determining Conformance To Specifications
ASME B89.7.3.2 – Guidelines for the Evaluation of Dimensional Measurement Uncertainty.

(Application for copies should be addressed to the ASME International, Three Park Avenue, New York, NY 10016–5990 or at URL http://www.asme.org.)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO GUIDE 98-3 – Uncertainty of Measurement – Part 3: Guide to the Expression of Uncertainty in Measurement.
ISO14253–1 – Geometrical Product Specifications (GPS) - Inspection by Measurement of Workpieces and Measuring Equipment - Part 1: Decision Rules for Proving Conformance or Non-Conformance with Specifications.

(Application for copies should be addressed to the International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case Postale 56, CH–1211 Geneva 20, Switzerland or at URL http://www.iso.org.

APPENDIX E

NCSL INTERNATIONAL (NCSL)

NCSL Z540–2 – U. S. Guide to the Expression of Uncertainty in Measurement.

(Application for copies should be addressed to the NCSL International, 2995 Wilderness Place, Suite 107, Boulder, CO 80301–5404 or at URL http://www.ncsli.org.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

APPENDIX F

TEST METHOD: RESISTANCE TO SOLDERING HEAT

F.1 SCOPE

F.1.1 Scope. This test method is intended to confirm that printed boards are capable of withstanding the elevated temperatures and thermal excursions associated with hot solder attachment. It is not intended to evaluate circuit pattern designs, poor thermal expansion matching, and mistreatment due to improper pre–heat or automation tools. This test method does not require the test facility to have the same processing equipment as employed by the user. The equipment and procedures listed herein are to serve as a guide with the test facility having the option, with qualifying activity approval, of substituting soldering heat tests using equivalent equipment that is capable of meeting the intent of this method with techniques that apply equal or better soldering tests. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

F.1.2 Purpose. This test is performed to determine whether printed boards can withstand the worst case effects of the heat to which they will be subjected during the assembly (soldering) process. The solder float method is a simulation of the conditions encountered in wave soldering of through–hole components in regards to radiated and conducted heat. The reflow oven test is intended to evaluate the impact of reflow techniques used for surface mount components to which printed boards may be exposed. The heat of soldering may cause mechanical damage to either the plated holes or base materials making up the printed board, or cause chemical changes to the base material that will impact long term reliability.

F.2 APPLICABLE DOCUMENTS

F.2.1 General. The documents listed in this section are specified in sections F.5 and F.6 of this appendix. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirement documents cited in sections F.5 and F.6 of this appendix, whether or not they are listed.

F.2.2 Non–Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

IPC – ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES (IPC)

| | | |
|---|---|---|
| J–STD–004 | – | Requirements for Soldering Fluxes. |
| J–STD–005 | – | Requirements for Soldering Pastes. |
| J–STD–006 | – | Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications. |

(Application for copies should be addressed to IPC – Association Connecting Electronics Industries, 3000 Lakeside Drive, Suite 309 S, Bannockburn, IL 60015–1249 or URL http://www.ipc.org.)

F.2.3 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

APPENDIX F

F.3 TEST SPECIMEN

F.3.1 Test specimen. The test specimen shall be a printed board, a portion of a printed board, or a test coupon as described in the applicable performance specification or MIL–PRF–31032 specification sheet.

F.3.2 Removal from production panel or board. The test specimen shall be removed from a production panel, printed board, or test coupon by routing or sawing. Shearing or punching shall not be used to remove the test specimen. Allow sufficient clearance from the area to be examined to prevent damage. The recommended minimum clearance is 2.54 mm (.10 inch).

F.4 APPARATUS

F.4.1 Desiccator. A desiccator of sufficient size to accommodate the test specimen with suitable desiccant.

F.4.2 Drying oven. The oven used for baking moisture out of the test specimens shall be capable of maintaining a uniform set temperature within the range of 105°C to 149°C.

F.4.3 Fixtures. Fixtures, when required, shall be made of a non-solderable material designed so that they will make minimum contact (i.e., minimum heat sink) with the test specimen. Further, they shall not place undue stress on the test specimen when fixtured.

F.4.4 Reflow chambers. The reflow chambers or equivalent (vapor phase reflow (VPR) chamber, infrared reflow (IRR) oven, air circulating oven) shall be of sufficient size to accommodate the test specimen to be tested. The chamber shall be capable of generating the specified heating rate, temperatures, and environments.

F.4.5 Solder pot. A static solder pot, of sufficient size to accommodate the test specimen, shall be used. This apparatus shall be capable of maintaining the solder at the temperature specified. The solder pot temperature shall be measured in the center of the pot at a depth of at least 20 mm (.750 inch), but no deeper than 25 mm (1 inch) below the surface of the solder.

F.4.6 Timing apparatus. A timing device, which can indicate time in seconds, shall be used to determine the time in which the test specimen is exposed to molten solder or air temperatures of the reflow chambers.

F.4.7 Temperature measurement (for reflow chamber).

F.4.7.1 Reflow chamber. Low mass thermocouples that do not affect the heating rate of the test specimen shall be used. A temperature recording device is recommended. The equipment shall be capable of maintaining an accuracy of ±1°C at the temperature range of interest.

F.4.7.2 Solder pot. Thermocouple indicator or other devices to measure the solder temperature.

F.4.8 Tongs. Tongs used to handle hot test specimens.

F.4.9 VPR fluid. A perfluorocarbon fluid that has a boiling point of 218°C ±5°C shall be used.

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F.5 MATERIALS

F.5.1 Solder. The solder or solder paste shall be tin-lead alloy with a nominal tin content of 50 percent to 70 percent in accordance with J–STD–005 or J–STD–006. When specified in the applicable performance specification or MIL–PRF–31032 specification sheet, other solders can be used provided they are molten at the specified temperature.

F.5.2 Flux. When flux is used, it shall conform to type R0L1 of J–STD–004, or as specified in the applicable performance specification or MIL–PRF–31032 specification sheet.

F.5.3 Solvent. A solvent, such as isopropyl alcohol, suitable for flux removal following the solder float tests.

F.6 PROCEDURE

F.6.1 Special preparation of test specimens. Any special preparation of test specimens prior to testing shall be as specified in the applicable performance specification or MIL–PRF–31032 specification sheet. This could include specific instructions such as application of flux or drying of the test specimen prior to the solder immersion or thermal excursion.

F.6.2 Preparation of solder bath. The molten solder shall be agitated to assure that the temperature is uniform. The surface of the solder shall be kept clean and bright.

F.6.3 Application of flux. When flux is used, the terminations (plated-holes or SMT pads) to be tested shall be immersed in the flux (see F.5.2), which is at room ambient temperature, to the depth specified. The duration of the immersion shall be from 5 seconds to 10 seconds.

F.6.4 Test conditions. Unless otherwise specified in the applicable performance specification or MIL–PRF–31032 specification sheet, all solder terminations of the test specimen shall be subjected to the heat cycles. There are six types of soldering techniques covered by these test conditions. The test conditions are outlined below and detailed in table F–I.

| | |
|---|---|
| Test condition A: | Solder float – Simulates high temperature wave solder. |
| Test condition B: | Solder float – Simulates medium temperature wave solder. |
| Test condition C: | Solder float – Simulates low temperature wave solder. |
| Test condition D: | Convection reflow – Simulates a low temperature forced air convection reflow environment with sample preconditioning. |
| Test condition F: | Convection reflow – Simulates a high temperature forced air convection reflow environment with sample preconditioning. |
| Test condition H: | Vapor phase reflow – VPR environment with preconditioning. |

F.6.4.1 Test condition A: Solder float – high temperature wave solder.

a. The test specimen shall be conditioned by baking in a drying oven for an appropriate period at 121°C to 149°C to remove the moisture in the test specimen. For referee purposes, a dry for a minimum of six hours at 121°C to 149°C shall be used. Thicker, or more complex, test specimens may require longer baking times. Remove the test specimen from the drying oven using tongs.

b. After removal from the drying oven, place the test specimen in a desiccator on a ceramic plate to cool to room temperature. Remove the test specimen from the desiccator using tongs.

c. Flux coat the surface and plated-through holes to ensure solder filling.

d. Verify that the solder temperature is as specified for test condition A in table F–I.

e. Remove the dross from the solder pot surface and lay the test specimen on the solder for 10 seconds +1, –0 seconds.

f. After removal of the test specimen from the solder, it shall be allowed to cool and stabilize at room ambient conditions. The test specimen shall be cleaned using an appropriate cleaning solution (see F.5.3).

g. The test specimen shall then be examined as specified in the applicable performance specification or MIL–PRF–31032 specification sheet.

F.6.4.2 Test condition B: Solder float – medium temperature wave solder. The test protocol of F.6.4.1 shall be followed, with the exception that the solder temperature as specified for test condition B in table F–I shall be used.

F.6.4.3 Test condition C: Solder float – low temperature wave solder. The test protocol of F.6.4.1 shall be followed, with the exception that the solder temperature as specified for test condition C in table F–I shall be used.

F.6.4.4 Test condition D: Convection air oven reflow soldering – low temperature with preconditioning.

a. The test specimen shall be preconditioned in a drying oven (see F.4.2) to remove moisture for a minimum of 6 hours at 105°C to 125°C. This preconditioning process is mandatory if this test condition is used for qualification purposes. Test specimens that are over 3.2 mm (.125 inch) in thickness may require longer preconditioning time to achieve acceptable moisture levels. Record the preconditioning time and temperature if different than those stated herein.

b. The test chamber shall be an air circulating oven as specified in F.4.4. The test chamber shall have adequate environmental controls to maintain the tolerance range and limits in accordance with the reflow profile described in table F–I. The test chamber shall accommodate verifiable calibration compliance and reflow profile generation.

c. A low mass thermocouple (see F.4.7) shall be attached tightly to the test specimen at an appropriate position away from its edges. The test specimen shall not be fluxed nor have solder paste applied.

d. The specific combination of temperature, preheat, duration, cool-down, and number of heat cycles shall be as specified by test condition D in table F–I and the applicable performance specification or MIL–PRF–31032 specification sheet.

e. The test specimen shall be placed into the test chamber and the temperature of the component ramped at a rate of 0.5°C/s to 2.0°C/s as measured by the thermocouple. The test specimen shall be at, or above, the maximum preheat temperature of 203°C for 80 seconds to 150 seconds. The test specimen shall be at, or above, the target reflow temperature of 225°C for 20 seconds. The test specimen shall then be allowed to cool at a rate of –1.0°C/s to –3.0°C/s to room ambient temperature or 30°C. The test specimen shall reach a temperature of 30°C or less prior to starting the next heat cycle. If the time it takes the test specimen to achieve thermal equilibrium of 30°C or less cannot be determined, then a five minute dwell between heat cycles shall be required. This constitutes one heat cycle. The test specimen shall be exposed to the number of heat cycles as specified in the applicable performance specification or MIL–PRF–31032 specification sheet.

f. The test specimen shall be inspected after the test as specified in the applicable performance specification or MIL–PRF–31032 specification sheet.

F.6.4.5 Test condition F: Convection air oven reflow soldering – high temperature with preconditioning. The test protocol of F.6.4.4 shall be followed, with the exception that the temperatures as specified for test condition F in table F–I shall be used.

F.6.4.6 Test condition H: Vapor phase reflow soldering with preconditioning.

a. The test specimen shall be preconditioned in a drying oven (see F.4.2) to remove moisture for a minimum of 6 hours at 105°C to 125°C. This preconditioning process is mandatory if this test condition is used for qualification purposes. Test specimens that are over 3.2 mm (.125 inch) in thickness may require longer preconditioning time to achieve acceptable moisture levels. Record the preconditioning time and temperature if different than those stated herein.

b. A VPR test chamber shall be used which is large enough to suspend the test specimen without touching the sides or the solution as specified in F.4.4. The VPR fluid shall be placed in the test chamber and shall be heated until it is boiling. The VPR fluid shall be allowed to boil for 5 minutes prior to suspending the test specimen.

c. A low mass thermocouple (see F.4.7) shall be attached tightly to the test specimen at an appropriate position away from its edges. Unless otherwise specified, the test specimen shall not be fluxed nor have solder paste applied.

d. The specific combination of temperature, duration of exposure, and number of heat cycles shall be as specified by test condition H in table F–I and the applicable performance specification or MIL–PRF–31032 specification sheet.

e. After chamber equalization, the test specimen shall be suspended into the vapor in a horizontal plane for the specified time. The test specimen shall not touch the solution. This constitutes one heat cycle. The test specimen shall be exposed to the number of heat cycles as specified in the applicable performance specification or MIL–PRF–31032 specification sheet. After the final heat cycle, the test specimen shall be allowed to cool and stabilize at room ambient conditions. If a solder paste was used, the test specimen shall be cleaned using an appropriate solution.

f. The test specimen shall be inspected after the test as specified in the applicable performance specification or MIL–PRF–31032 specification sheet.

F.7 EXAMINATIONS AND MEASUREMENTS.

F.7.1 Examinations and measurements. Examinations and measurements to be made before and after the test, as applicable, shall be as specified in the applicable performance specification or MIL–PRF–31032 specification sheet. After the procedure, the test specimens shall be allowed to cool and stabilize at room ambient conditions, for the time specified in the applicable performance specification or MIL–PRF–31032 specification sheet.

F.7.2 External examination. When specified in the applicable performance specification or MIL–PRF–31032 specification sheet, external examination of the test specimen shall be made after the test to check for heat damage.

F.7.3 Internal examination. When specified in the applicable performance specification or MIL–PRF–31032 specification sheet, internal examination via microsection of the test specimen shall be made after the test to check for heat damage.

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F.8 SUMMARY.

F.8.1 Summary. The following details shall be specified in the applicable performance specification or MIL–PRF–31032 specification sheet:

a. The use of heat sinks or shielding is prohibited except when they are part of the test specimen.

b. Test fixtures, if different from that specified (see F.4.3).

c. Solder, if different from that specified (see F.5.1).

d. Flux, if applicable and if different from that specified (see F.5.2).

e. Special preparation of specimens if applicable (see F.6.1).

f. Test condition letter (see F.6.4).

g. Cooling time prior to final examinations and measurements (see F.7).

h. Examinations and measurements before and after test, as applicable (see F.7).

i. Method of internal inspection, if required (see F.7.3).

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TABLE F–I. Test conditions.

| Solder technique simulation | Test condition | Temperature (°C) | Time (s) | Temperature ramp/ immersion and emersion rate | Number of heat cycles |
|---|---|---|---|---|---|
| Solder float – high temperature wave solder | A | 288 ±5 (solder temp) | 10 ±1 | | 1 |
| Solder float – medium temperature wave solder | B | 260 ±5 (solder temp) | 10 ±1 | | 1 |
| Solder float – low temperature wave solder | C | 232 ±5 (solder temp) | 10 ±1 | | 1 |
| Convection air oven reflow – low temperature with preconditioning | D | 230 ±5 (test specimen temperature) | | Min/max preheat rate: 0.5 / 2.0°C/s<br>Time above 203°C, 80 to 150 s<br>Time above 225°C, 20 s minimum<br>Min/max cool down rate: –1.0 / –3.0°C/s | 2 – 6 |
| Convection air oven reflow – high temperature with preconditioning | F | 260 ±5 (test specimen temperature) | | Min/max preheat rate: 0.5 / 2.0°C/s<br>Time above 230°C, 80 to 150 s<br>Time above 255°C, 20 s minimum<br>Min/max cool down rate: –1.0 / –3.0°C/s | 2 – 6 |
| Vapor phase reflow | H | 218 ±5 (vapor temp) | 60 ±5 | | 1 – 3 |

APPENDIX F

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APPENDIX G

TEST METHOD: SEQUENTIAL ELECTROCHEMICAL REDUCTION ANALYSIS (SERA) SOLDERABILITY

G.1 SCOPE

G.1.1 Scope. This test method describes the method and procedure used to evaluate oxidation levels on solderable surfaces. The type and quantity of oxides on copper, tin, and lead surfaces have a significant impact on solderability. The procedure involves using electrochemical reduction techniques to determine the type and quantity of oxide on plated-through holes, attachment lands, and printed board surface conductors. The sequential electrochemical reduction analysis (SERA) solderability test method is offered as an alternative to other solderability test methods required by this document. This test method shall not be contractually imposed upon either the contractor or subcontractor. This appendix is not a mandatory part of the specification. The information contained herein is intended for compliance only when volunteered as an alternative to the other solderability test methods detailed.

G.2 APPLICABLE DOCUMENTS

G.2.1 General. The documents listed in this section are specified in sections G.3, G.4, and G.5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirement documents cited in sections G.3, G.4, and G.5 of this specification, whether or not they are listed.

G.2.2 Government documents.

G.2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL SPECIFICATIONS

A–A–59282 – Chemicals, Analytical; General Specification for.

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or https://assist.daps.dla.mil/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111–5094.)

G.2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

IPC – ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES (IPC)

J–STD–004 – Requirements for Soldering Fluxes.

(Application for copies should be addressed to IPC – Association Connecting Electronics Industries, 3000 Lakeside Drive, Suite 309 S, Bannockburn, IL 60015–1249 or URL http://www.ipc.org.)

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THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC. (IEEE)

IEEE–488 – Standard Digital Interface For Programmable Instrumentation.

(Copies of these documents are available online at URL http://ieee.org or from the IEEE Operations Center, 445 Hoes Lane, Piscataway, New Jersey 08854–1331.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

G.2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

G.3 DEFINITIONS

G.3.1 Sequential Electrochemical Reduction Analysis (SERA). A chronopotentiometric reduction method for assessing tin-lead finish solderability.

G.4 TESTING

G.4.1 Apparatus (see figure G–1).

G.4.1.1 Reservoir (see detail A). The reservoir shall be a container constructed of a nonmetallic, nonreactive material with a minimum volume of 500 ml. The reservoir shall have an inlet/outlet port, test head chamber port, and a saturated calomel electrode (SCE) reference electrode port. The inlet/outlet port shall be connected to a vacuum trap tube. The inlet/outlet port shall incorporate a diffuser to aid in the effectiveness of the inert gas purging. Polypropylene tubing may be used for connection tubing. All connection fittings shall be of a nonreactive material. The reservoir shall have the capability of maintaining a positive pressure environment. The reservoir shall be emptied and rinsed with deionized water for every 16 hours of testing.

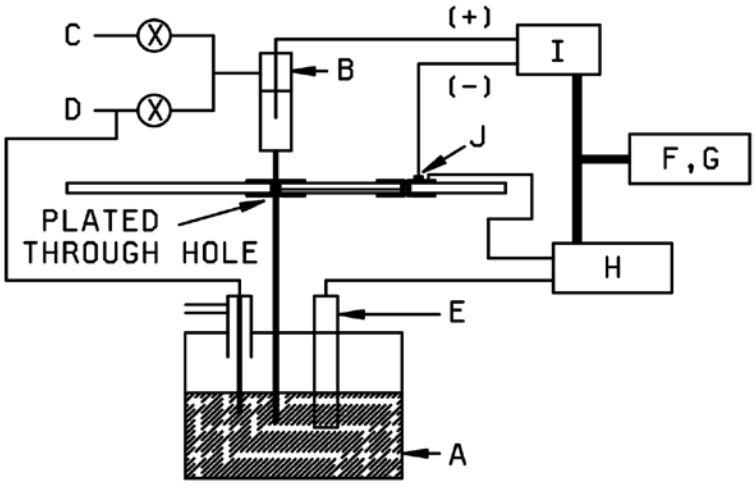


FIGURE G–1. Schematic of SERA plated through hole apparatus.

G.4.1.2 Test head (see detail B). The test head shall be constructed of a nonmetallic, nonreactive material. The test head shall have ports to allow inert gas purging and intake/expulsion of borate buffer solution. The test head shall have either an optical or mechanical means of aligning the test head chamber over the test plated-through hole. The test head shall use Vitron, or equivalent, o–rings for the test head to test surface interface seals. These o–rings shall be replaced after every 8 hours of testing unless integrity of the o–rings can be documented for extended periods. The test head shall have the capability of maintaining a positive pressure environment.

G.4.1.3 Vacuum pump (see detail C). A vacuum pump shall be used to draw buffer solution into and out of the test head compartment. The vacuum pump shall be able to draw minimum vacuum of 5 inches of Hg (16.9 kPa).

G.4.1.4 Gas regulator (see detail D). An in-line gas regulator shall be used to monitor the flow of the inert purging gas. The gas regulator shall be able to measure a minimum of 1 cubic foot per hour (0.02832 cubic meters per hour) at standard temperature and pressure.

G.4.1.5 SCE reference electrode (see detail E). The reference electrode shall be a SCE reference electrode with a temperature range of –5°C to +60°C and a Ph range of 0–14. The SCE reference electrode shall be stored in such a manner as to prevent drying out (either in a saturated KCI solution or in accordance with the manufacturer's instructions). The SCE reference electrode shall be calibrated in accordance with the manufacturer's instructions once every 30 days.

G.4.1.6 Computer (see detail F). The computer shall be equivalent to, or better than, a MS-DOS compatible, 80286–12MHz, with 512 Kbyte of internal memory and floppy and hard disk drives.

G.4.1.7 IEEE-488 interface card (see detail G). An IEEE–488 interface card is required for data acquisition between the computer, the digital multimeter, and the programmable current source.

G.4.1.8 Digital multimeter (see detail H). A digital multimeter is required to measure the voltage changes during the SERA reduction. The digital multimeter shall have the following characteristics:

a. A measurable voltage range of 0 V to –2.0 V.

b. A voltage measurement tolerance of ±5 mV.

c. Voltage measurement root-mean-square noise level should not exceed 10 Mv.

d. Input impedance should be greater than 1 G-Ohm.

G.4.1.9 Programmable current source (see detail I). A programmable current source is required to apply a constant current during the SERA reduction. The programmable current source shall have the following minimum characteristics:

a. The applied current should be variable in 0.1 microamp steps between 1.0 microamps and 10 microamps.

b. The applied current should remain constant within ± 5 percent.

G.4.1.10 Printed board contact pin (see detail J). A contact pin is required to complete the electrical circuit with the test plated-through hole. The printed board contact pin shall not exert a force of greater than .5 pounds (0.23 Kg) nor alter the plated-through hole form, fit, or function.

G.4.2 Materials.

G.4.2.1 Borate buffer solution. The SERA test requires the use of a borate buffer solution. This solution uses reagent grade boric acid, sodium borate ($Na_2B_40_7 * 10\ H_20$), and deionized water. The recipe is 6.18 grams/liter boric acid and 9.55 grams/liter of sodium borate. The Ph of the borate buffer solution shall range in the range of 8.3 to 8.4. Adjustments to the buffer Ph shall be made using either boric acid or sodium borate additions.

G.4.2.2 Inert gas. An inert gas is required to purge oxygen from the system. Either argon or ultra high purity (99.998 percent) dry nitrogen shall be used.

G.4.2.3 Deionized water. Deionized water comprises a portion of the borate buffer solution and shall be used to rinse the test plated-through hole after completion of the SERA analysis. The deionized water shall be 1 Megohm conductivity or better.

G.4.2.4 Isopropyl alcohol. Isopropyl alcohol is used to rinse the test plated-through hole after the competition of the SERA analysis. Reagent grade isopropyl alcohol, in accordance with A–A–59282, shall be used.

G.4.2.5 Potassium chloride solution (KCl). The SCE reference electrode may be stored in a saturated KCl solution. This solution uses reagent grade potassium chloride, in accordance with A–A–59282, in a saturated solution form.

G.5 PROCEDURES

G.5.1 General. The test procedure shall be performed on three plated-through holes randomly chosen on the printed board or representative test coupon. The SERA test shall be performed just prior to packaging for storage or shipment or immediately upon removal from the manufacturer's protective package. During handling, care shall be exercised to prevent the surfaces being tested from being abraded or contaminated by grease, perspirants, or abnormal atmosphere. The test procedure consists of the following operations:

a. Proper preparation of SERA system (see G.5.2).

b. Application of test method (see G.5.3).

c. Evaluation of test data (see G.5.4).

d. Proper post–test preparation of SERA system (see G.5.5).

G.5.2 Preparation of SERA systems.

a. Initiate inert gas flow into system and allow a minimum of 10 minutes to elapse prior to testing.

b. Turn on digital multimeter and programmable current source and allow a minimum of 10 minutes to elapse prior to testing.

c. Remove reference electrode port and rinse with deionized water. Replace reference electrode port and add sufficient quantity of borate buffer solution to immerse the SCE reference electrode a minimum of 25.4 mm (1 inch).

d. Remove SCE reference electrode from storage container. Rinse with deionized water, wipe with clean soft cloth, and place into reference electrode port. Attach system electrical connections in accordance with figure G–1.

e. Remove and replace test head o–ring seals as required (see G.4.1.2).

f. Close SERA test head together thus seating o–rings together on a representative sample plated-through hole and perform vacuum check on system. No visible air bubbles shall be detected in the test head chamber which would indicate improper sealing.

G.5.3 Application of test method.

a. The test operator shall record the specimen lot date code and manufacturer for each individual printed board. An individual printed board reference chart for the test plated-through holes and printed board contact pin locations shall be maintained for each test specimen configuration.

b. Insert test specimen onto SERA test head and allow a minimum of 4 seconds for inert gas purging of the test head. Ensure inert gas bubbling is occurring in the reservoir tube.

c. Attach the printed board contact pin.

d. Attach electrical source leads.

e. Draw borate buffer solution into test head chamber a minimum of 75 percent of chamber height. Visually monitor test head chamber for leaks.

f. Partially flush test head chamber to 50 percent height to dislodge any gas bubbles which could be trapped in test hole.

g. Input computer data for test specimen and test hole identification. Set current density at 30 µamp per centimeter squared (plated-through hole area shall be calculated as specified in G.5.3.1), test duration at a minimum of 400 seconds, the number of open circuit samples to be measured, and the number of systems measurements at one reading per second. The minimum test duration may be reduced provided complete plated-through hole reduction has been achieved.

h. Perform SERA test to test duration completion.

i. Remove electrical source leads.

j. Remove the printed board contact clamp.

k. Flush borate buffer solution from test hole.

l. Remove test specimen from SERA test head.

m. Rinse test plated-through hole with deionized water saturated cotton swab for a minimum of 3 seconds, then rinse test plated-through hole with isopropyl alcohol saturated cotton swab for a minimum of 3 seconds. Allow test plated-through hole to air dry. The rinsing operations may be conducted for all test holes as a one time operation provided the rinsing operation is completed within 10 minutes of completion of the last test hole on that individual printed board specimen. Other documented rinsing operations may be used provided their effectiveness is as good as or better than the cotton swab rinse process.

G.5.3.1 Plated-through hole area calculation. The area of plated-through holes shall be determined using:

$$\text{Area} = (2)(\pi)(R1)(H) + [(2)(\pi)(R2^2) - (2)(\pi)(R1^2)]$$

where

H = Printed board specimen thickness.
R1 = Plated-through hole radius.
R2 = O–ring internal radius.

An example of the calculation is as follows:

H = See table G–I for the values for H.
R1 = Plated-through hole radius = 0.046 cm nominal.
R2 = O–ring internal radius = 0.075 cm.

$$\text{Area} = (2)(\pi)(0.046)(H) + [(2)(\pi)(0.075)^2 - (2)(\pi)(0.046)^2]$$

$$= (0.22890)(H) + [0.03534 - 0.013295]$$

$$= 0.2890 \text{ cm } (H \text{ cm}) + [0.022045 \text{ cm}^2]$$

TABLE G–I. SERA plated-through hole example calculation data.

| Printed board thickness (millimeters) | H (inches) | Area (centimeters$^2$) |
|---|---|---|
| 0.508 | .020 | 0.0367 |
| 0.762 | .030 | 0.0441 |
| 1.016 | .040 | 0.0514 |
| 1.270 | .050 | 0.0587 |
| 1.524 | .060 | 0.0661 |
| 1.778 | .070 | 0.0734 |
| 2.032 | .080 | 0.0808 |
| 2.286 | .090 | 0.0881 |
| 2.540 | .100 | 0.0955 |
| 2.794 | .110 | 0.1028 |

G.5.4 Evaluation of test data. The change in reduction voltage shall be plotted versus the charge density (current density against time). This SERA curve generated shall be differentiated and then incorporate the following moving window average, curve smoothing function:

V(n) = SUM [V(n-5) through V(n+5)] / 11

The following eight SERA parameters shall be calculated from the differentiated and smoothed SERA curve using the following threshold limits listed below. Figure G–2 illustrates these parameters and threshold limits on an example SERA curve.

1. Voc = The final open circuit voltage measured for the SERA differentiated/smoothed curve.
2. Q1 = The area under the curve defined by: Nmin1 threshold value (defined constant value).
3. V2 = The voltage on the differentiated/smoothed curve defined by: (Nmin3 + Nmin1 threshold values) / 2.
4. Q2 = The area under the curve defined by: Nmin3 threshold value – Nmin 1 threshold value.
5. V3 = The voltage on the differentiated/smoothed curve defined by: (Nmin5 + Nmin3 threshold value)/2.
6. Q3 = The area under the curve defined by: Nmin5 threshold value – Nmin3 threshold value.

7. Vf = Most negative reduction voltage measured for the SERA differentiated/smoothed curve.

8. Qt = Total reduction charge (summation of Q1 + Q2 + Q3) for the SERA differentiated/smoothed curve.

Threshold constraints:

a. Constant = First point on curve for measured voltage before applying current.

b. Nmin1 = First point on curve where measured voltage < –0.85 volts.

c. Nmin3 = Minimum calculated dVoltage between N1 and N2.

N1 = First point between Nmin1 and N2 where calculated Dvoltage < –0.003 volts.

N2 = Last point on curve where measured voltage < –1.3 volts.

d. Nmin5 = Last point on curve where calculated Dvoltage < –1.3 volts.

Unless otherwise agreed upon by the printed board fabricator and user, the SERA parameter for V2 shall meet the minimum acceptable value listed in table G–II. The other seven SERA parameters shall be within the ranges listed in table G–III for a ROM0 or ROM1 flux in accordance with J–STD–004. The printed board soldering performance in the manufacturing process will be directly related to the specific flux used in the soldering process. It is the printed board users responsibility to document the critical SERA parameter levels for other specific flux systems.

TABLE G–II. Minimum acceptable V2 value.

| SERA parameter | Minimum acceptable value |
|---|---|
| V2 | Equal to or more positive than –1.07 V |

TABLE G–III. SERA values for ROM0 or ROM1 flux in accordance with J–STD–004.

| SERA parameter | Minimum acceptable value |
|---|---|
| Voc | –0.461 to –0.613 V |
| Q1 | 0.0 to +1.312 mC/cm$^2$ |
| Q2 | 0.0 to +3.823 mC/cm$^2$ |
| Q3 | 0.0 to +3.299 mC/cm$^2$ |
| V3 | –1.29 to –1.412 V |
| Vf | –1.365 to –1.466 V |
| Qt | +2.005 to +5.985 mC/cm$^2$ |

G.5.5 Proper post test preparation of SERA system.

a. Shut off inert gas flow into system.

b. Shut off digital multimeter and programmable current source.

c. Remove SCE reference electrode, rinse with deionized water and wipe clean with clean soft cloth. Place SCE reference electrode in storage container.

d. Remove reference electrode port and dump out borate buffer solution. Rinse inner and outer surfaces of reference electrode port with deionized water. Replace reference electrode port into system.

e. Remove o–rings and dispose of as required (see G.4.1.2). Rinse test head o–ring seal with deionized water and wipe dry with clean soft cloth.

f. Empty reservoir of borate buffer solution, rinse with deionized water, and refill with buffer solution as required (see G.4.1.1).

G.6 NOTES

G.6.1 Note. The equipment described herein is a result of a United States Army MANTECH Program investment. SERA is a scientific means of measuring solderability of circuit boards and components. The technology is based upon measurements of the type and quantity of oxides using SERA method. Rockwell International at Thousand Oaks, CA is the patent holder, and the United States Army MANTECH Program was successful in developing, proving, commercializing, and standardizing the equipment and processes. Round robin tests by a Government-industry team were successfully completed in the standardization effort. The United States Army has a perpetual royalty free license and the equipment is currently on a number of weapons production lines. The technical point of contact for future inquiries should be directed to the sole source supplier:

ECI Technology
1 Madison Street
East Rutherford, NJ 07073

Phone: (973) 773-8686
Facsimile: (973) 773-8797
Electronic mail: ecitechnology@eci.com
URL: http://www.ecitechnology.com

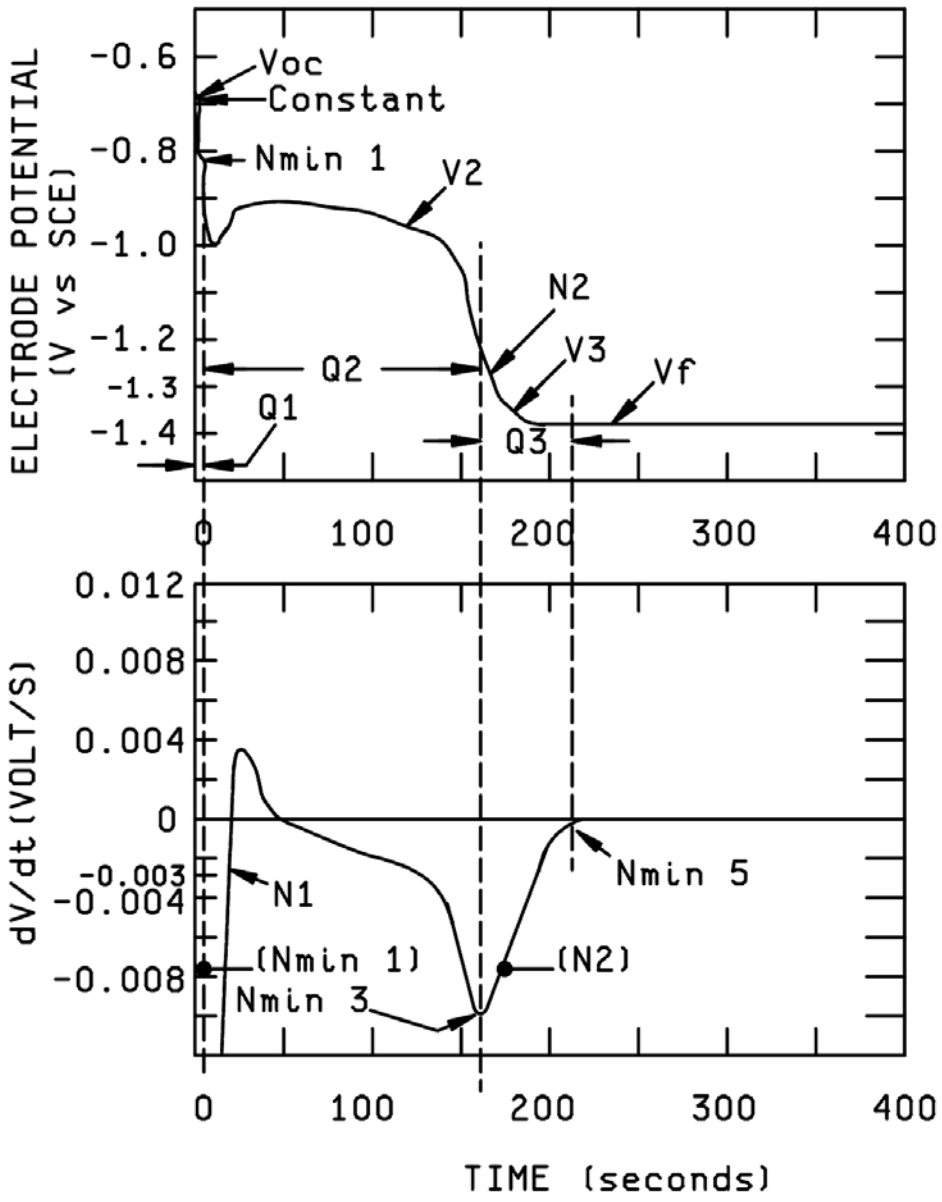


FIGURE G–2. Example SERA differentiated/smoothed curve.

Custodians:
Army – CR
Navy – EC
Air Force – 85
DLA – CC

Review activities:
Army – MI
Navy – MC, SH
Air Force – 99
Other – NRO

Preparing activity:
DLA – CC

(Project 5998–2012–040)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.daps.dla.mil/.